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NEW TRENDS IN CIVIL AVIATION 2013

FOREWORD

Professionals from the air transport industry and airspace meet every year to present their ideas on the ‘New trends’ conference. When I looked back to the old proceedings from the former years I found that we did not defined what the ‘New trends’ are. Is a new trend the most recent decision of the European Parliament to cut down budget for the next Transport Framework Programme – Horizon 2020 by 20%? Well nothing new for us. The budget cuts are very popular in all European countries nowadays especially in the ‘useless’ sectors like education, research and health services.

To give a floor to ‘young professionals’ is also nothing new and the ‘young professionals’ of the 1999, when this conference took-off for the first time, become quite experienced.

What is new and quite different, comparing to former years, is the growing interest from the industry to participate in the conference. New is also involvement of private sector in research and development. This new trend – supported by the infrastructural EU funds projects, can partially replace insufficient financing on the state level. The new is also increased co-operation between the academia and the industry resulting in shortening time between research, development and implementation of the research results. However, these new trends should be further supported and enhanced from both sides – industry and academia.

Are there any threats to those tendencies? Well, both our nations, but more the Czechs than Slovaks are typical for constant moaning, complaining, making it difficult to adversity. Certainly we are not able to compare our conditions for research with those in Austria, Germany, France but even with the Czech republic. Nothing less we should consider the crisis more as opportunity and challenge then handicap. More difficult conditions have always been the basis of natural selection in which they survive better. I have no doubts that we will the winners.

Prof. Antonín Kazda

Head of Air Transport Department

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NON-DESTRUCTIVE TESTING IN AIRCRAFT MAINTENANCE

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***Abstract** – Non-Destructive Testing (NDT) evaluates material properties and quality of manufacture for expensive components or assemblies without damaging the product or its function. Instead of statistical sampling techniques that use only surface measurements or require the destructive testing of selected components from a production lot, NDT is used when these testing techniques are cost prohibitive or ineffective. Typically, NDT has been associated with the aircraft operation.*

Key words – Non-Destructive Testing, Maintenance, Aircraft

I. INTRODUCTION

Management of maintenance activities at facilities on aircraft is a complex and expensive task. This paper presents a variety of techniques that can monitor equipment condition and anticipate failure. For some noncritical, inexpensive, and easily replaced components, run-to-failure method may be an acceptable practice. For large, complicated, expensive, critical items, run-to-failure may be unacceptable. Maintenance to maximize service life of equipment or components and surveillance of performance degradation can allow repairs/replacement without interruption of critical activities. For certain installations, it may be more economical to use contract services to maintain infrequent, complex, and expensive equipment and processes.

Nondestructive testing is defined as: "The determination of the physical condition of an object without affecting that object's ability to fulfill its intended function. Nondestructive testing techniques typically use a probing energy form to determine material properties or to indicate the presence of material discontinuities (surface, internal or concealed)."[1].

II. NEW MATERIALS DEVELOPMENT

The implementation of new materials for fuselages requires a large number of tests and validations. The spectrum of investigations reaches from a simple material specimen over coupons up to a complete fuselage. With all of the tests static and dynamic properties are studied. Important for the security is the damage tolerance behavior of the fuselage structures. The design of further fuselages is strong influenced by new innovative materials and joining technologies.

New aluminum alloys with lower density and welding suitability are developed. Alloy systems Al-Mg-Si-Cu (AA6013), Al-Mg-Li und Al-Mg-Sc, the extension of the application of titanium alloys and the development of high-strength magnesium alloys as well as the application of carbon fiber reinforced plastic materials are important aspects for new design, inspection and testing demands [2].

III. TEST PHILOSOPHY

The test pyramid for all mechanical structural tests (static and fatigue) consider material tests at coupon level, different levels of structural and component testing up to testing of complete aircraft structures (major tests), fig. 1.

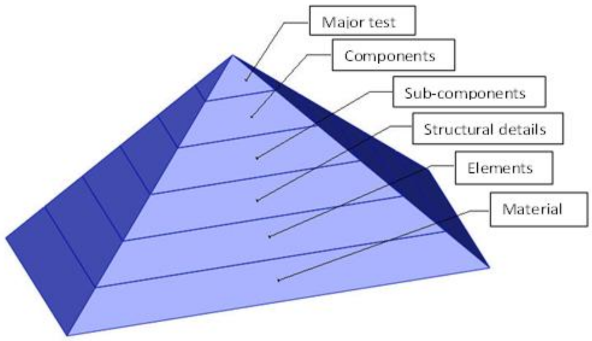

***Figure 1** – Test pyramid*

IV. NDT METHODS

There are seven common methods utilized for nondestructive testing and the selection of the method depends on the physical properties of the item being tested. These methods are:

- Visual Inspection
- Liquid Penetration Inspection
- Acoustic Emission
- Magnetic Particle Inspection
- Eddy Current Inspection
- Ultrasonic Inspection
- Radiography

VISUAL INSPECTION

Visual scanning, inspection or testing can successfully detect these unacceptable surface discontinuities without applying expensive test methods. Despite advances in other NDT technologies, visual inspection will likely remain the first inspection method usedin many field applications. As new mechanical and optical aids become available, the reliability of visual inspection will increase to more acceptable levels. It is expected that additional visual inspection standards will be developed to provide guidance in applying visual inspection for nondestructive testing. Visual inspection will continue to be an important NDE inspection approach that will often identify areas of structures or components where more advanced NDE methods need to be applied.

LIQUID PENETRATION INSPECTION

Liquid penetrant testing is one of the oldest and simpliest NDT methods where its earliest versions (using kerosene and oil mixture) dates back to the 19th century. This method is used to reveal surface discontinuities by bleedout of a colored or fluorescent dye from the flaw. The technique is based on the ability of a liquid to be drawn into a "clean" surface discontinuity by capillary action. After a period of time called the "dwell time", excess surface penetrant is removed and a developer applied. This acts as a blotter that draws the penetrant from the discontinuity to reveal its presence.

Penetrant inspection consists essentially of the following sequence of operations:

- The surface of components to be inspected is prepared by cleaning, creating a clean drysurface.
- Penetrant is applied to the prepared surface to be inspected.
- A period of time is allowed for it to enter any discontinuity open to that surface.
- The excess penetrant is removed in such a manner that will ensure retention of penetrantinside of the discontinuity.
- A developer agent is applied to draw the penetrant liquid from the discontinuities out to thesurface and thereby give an enhanced indication of such discontinuities.
- The discontinuities are then visually examined and assessed under appropriate viewingconditions.
- The part is then cleaned and, as necessary, a corrosion preventative is applied.[4]

ACOUSTIC EMISSION

Acoustic Emission (AE) refers to the generation of transient elastic waves produced by a sudden redistribution of stress in a material. When a structure is subjected to an external stimulus (change in pressure, load, or temperature), localized sources trigger the release of energy, in the form of stress waves, which propagate to the surface and are recorded by sensors. With the right equipment and setup, motions on the order of picometers (10 -12 m) can be identified. In composites, matrix cracking and fiber breakage and debonding contribute to acoustic emissions. AE's have also been measured and recorded in polymers, among other materials.

MAGNETIC PARTICLE INSPECTION

Magnetic particle inspection (MI) is a very popular, low-cost method to perform nondestructive examination of ferromagnetic material. Ferromagnetic is defined as "a term applied to materials that can be magnetized or strongly attracted by a magnetic field." MI is an NDT method that checks for surface discontinuities but can also reveal discontinuities slightly below the surface. magnetic particle examination can be a useful nondestructive examination method during new construction and in-service inspections. It can only be used on ferromagnetic materials; therefore, it is not the best method for all applications. For quick, low-cost inspections, MI is often the best NDT method for detecting surface and slightly subsurface discontinuities. [3]

EDDY CURRENT INSPECTION

Eddy Current Inspection (EI) method has a wide usage in the field of Industry. Especially, aircraft maintenance field has so many applicable areasforthis method. In addition, a wide variety of inspections and measurements may be performed with the eddy current methods that are beyond the scope of other techniques. Measurements of non-conductive coating thickness and conductivity can be done. Conductivity is related to the composition and heat treatment of the test material. Therefore, the eddy current method can also be used to distinguish between pure materials and alloy compositions and to determine the hardness of test pieces after heat treatments. [5]

This method is widely used to detect surface flaws, to sort materials, to measure thin walls from one surface only, to measure thin coatings and in some applications to measure casedepth. This method is applicable to electrically conductive materials only. In the method eddy currents are produced in the product by bringing it close to an alternating current carrying coil. The alternating magnetic field of the coil is modified by the magnetic fields of the eddy currents. This modification, which depends on the condition of the part near to the coil, is then shown as a meter reading or cathode ray tube presentation. [6]

ULTRASONIC INSPECTION

Ultrasonic inspection uses high frequency sound waves (typically in the range between 0.5 and 15 MHz) to conduct examinations and make measurements. In ultrasonic inspection use is made of the basic physical property that sound waves travel at known constant velocities through any sympathetic medium. By measuring the time for a sound wave to travel through a material it can be determined how far that wave has travelled. In this way sound waves can be used to measure distances. Use can also be made of the fact that sound waves are reflected at an interface between two materials such as steel and air to detect defects.

Aircraft have many systems that can be checked ultrasonically. Some of the more common applications include:

- Locate cabin pressure leaks
- Locate leaks in oxygen systems
- Locate tire leaks
- Locate problems in hydraulic system, valves and actuators
- Locate leaks in cockpit windows & doors
- Locate problems with bearings, pumps, motors and gears

- Locate leaks in floatation devices (seaplane floats)
- Locate leaks in fuel cells
- Detect & locate corona affecting electronics
- Detect & locate arcing & sparking in electrical systems

RADIOGRAPHY

Radiography uses radiation energy to penetrate solid objects in order to assess variations in thickness or density. The second part of the process involves capturing a shadow image of the component being inspected on film using procedures similar to those that technicians used when the technology was first developed. Identifying density differences on an X-ray, which indicate flaws or cracks, is still the foundation of radiographic analysis. Radiography basically involves the projection and penetration of radiation energy through the sample being inspected. The radiation energy is absorbed uniformly by the material or component being inspected except where variations in thickness or density occur. The energy not absorbed is passed through to a sensing medium that captures an image of the radiation pattern. The uniform absorption and any deviations in uniformity are subsequently captured on the sensing material and indicate the potential presence of a discontinuity.[7]

V. CONCLUSION

Non-Destructive Testing is the term given to the process of inspection of either a component or structure in which the item being tested is not changed or destroyed. This means that after inspection the item being tested can be used for its originally designed purpose should it not be found to have a fault. As such NDT may be used for the purposes of monitoring quality during manufacture of items such that they may be checked for defects or imperfections, checking fatigue or deterioration of items already in use such as cracking, and assessment of defects where defects are analyzed to determine the items suitability to performing the task it was designed for.

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PROPELLER DESIGN FOR ELECTRIC POWEREDLIGHT AIRCRAFTS

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Abstract – *The recent years have witnessed a flurry of exciting developments in the field of electric powered aircraft.However, the energy capacity constraints with current electrical power sources often limit the flight times of these aircraft to little more than one hour. Consequently, there is a big demand for efficiency increasing of whole propulsion system with emphasis on propeller performance and noise characteristics.*

Key words – Propeller, electric powered aircraft, batteries

I. INTRODUCTION

In the following text, brief introduction into the electric propulsion technology will be presented. In recent years big emphasis is given to green technology and environment noise reduction. The electric and hybrid propulsion systems are subject to rapid development not only in automotive industry but also in aerospace. Rapid development is remarkable in the field of battery design, electric engine design which is pushed by automotive industry. In the field of propeller design the innovation are more conservative but goes also forward.

II. ELECTRIC MOTORS

More than 100 different electric motors can be found in modern vehicles. The great variety of motor topologies and the different specifications of EVs result in a segmented market with DC, Induction (IM), Synchronous Permanent Magnet (SPM) and Synchronous Brushed (SBM) motors already commercially available. A fifth topology, the Reluctance Motor (RM), has been proposed due to favourable characteristics but has not yet been released commercially in EVs.

The efficiency of electric motors depends on the working points that each driving cycle applies to the motor, as in IC motors. There is no standard stand alone figure of the efficiency rating for variable speed motors. If motors with the same peak efficiency are compared, PM motors are more efficient in overload transients at constant speed, while RM motors have better performances at high speed overloads. RMs' control allows high speed operation but the efficiency decays rapidly at low speed. SB motors have lower peak efficiency than PM motors, but the efficiency remains high in a wide operational range, and their control allows high speed operation. The efficiency is also dependant on the voltage level. High voltage rated drivelines are intrinsically more efficient. On the other hand, the efficiency drops when the driveline is operated below rated voltage. This happens at low State of Charge.

DC MOTORS

DC motors consist of a stator with a stationary field and a wound rotor with a brush commutation system. The main advantages of this type of motors are: the technology is well established, reliability, inexpensive and have a simple and robust control. DC motors were the preferred option in variable speed operation applications before the development of advanced power electronics. The main disadvantages are: low power density compared with alternative technologies, costly maintenance of the coal brushes (about every 3,000 hours) and low efficiency, although efficiencies over 85% are feasible.

Figure 1 *– YASA-750 Motor*

SYNCHRONOUS PERMANENT MAGNET MOTORS

Permanent Magnet (PM) motors are characterized by their constant rotor magnetization. PMs in the rotor induce high magnetic fields in the air gap, without excitation currents, leading to high power density. Excitation currents represent about half of the losses in the form of Joule losses for non self excited synchronous motors. Thus, PM motors are intrinsically very efficient and require less cooling due to the lack of exciting currents. This comes at the cost of a more complex control as the excitation field may not be regulated. For historical reasons Synchronous Permanent Magnet Motors (SPM) are also known as Brushless Permanent Magnet (BPM).

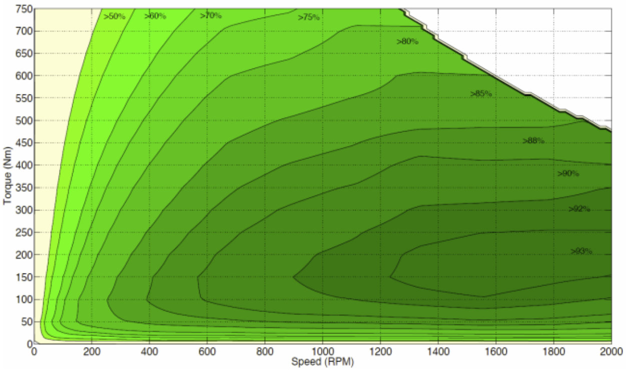

***Figure 2** – Engine torque vs rpm YASA-750 Motor*

INDUCTION MOTORS

Induction motors (IM) are also known as asynchronous motors or squirrel cage motors. Their main advantage is their construction simplicity. Induction motors are inexpensive, very robust, require little maintenance and are reliable. The International Electrotechnical Commission (IEC) standard IE3 sets the efficiency at over 95% for static applications. In EVs, the peak efficiency is sacrificed to obtain a better performance curve over a wider speed range. 75% efficiency is considered a good figure of merit for a small variable speed motor.

SYNCHRONOUS BRUSHED MOTORS

Synchronous Brushed Motors are used by Renault in their next midsized models. This type of motor has a coil in the rotor connected to a stationary voltage source through a slip ring. The electric current flows from a stationary coal brush through a rotating slip ring in steel. The magnetic field in the rotor is induced by the field current through the rotor coil. The rotor is robust and the temperature is only limited by the conductor insulation. The possibility to regulate the magnetic flux linkage is the main advantage of this technology. Also, the technology offers a high starting torque and the control is simpler and more robust than for SPM. However, the magnetizing current is subjected to Joule losses. Thus, full load operation efficiency is lower than for comparable machines without currents in the stator i.e. RMs and SPMs.

RELUCTANCE MOTORS

Reluctance Motors (RM) have gained attention due to the concern of price increase or shortage of magnetic material when the electric vehicles enter mass production. RMs main characteristic is the use of rotor salient poles. The very robust rotor is cheap to produce and not temperature sensitive. The peak efficiency is equivalent to IM while the efficiency remains high over a wide speed range. Efficiencies over 95% have been reported. The high rotor inductance ratio makes sensorless control easier to implement. The high ripple torque resulting in higher noise and vibrations is the main drawback. So far, the reluctance motor has not been used in electric vehicles, despite high interest for the good performance reported in literature and successfully demonstrated prototypes.

III. BATTERIES

A battery pack as primary energy source is preferred to any other power source, like for example fuelcells, for its reversibility. The battery can operate as a power source as well as an energy storage device. In this respect, lithium-ion cells have considerably greater energy density than previously-used battery chemistries (e.g. lead acid, nickel cadmium and nickel metal hydride). This makes them particularly suitable for aerospace and automotive applications. They are also considered safer, less toxic, and are more highly energy efficient with significantly longer cycle life.

The specific power and specific density of various rechargeable batteries are shown in the Figure 3 below. Lithium polymer batteries are placed in the upper range of specific density in comparison with high and medium power Lithium ion batteries. Only high energy Li-ion batteries are above them in terms of specific energy. On the other hand, Li Polymer Batteries need to increase the values of specific power.

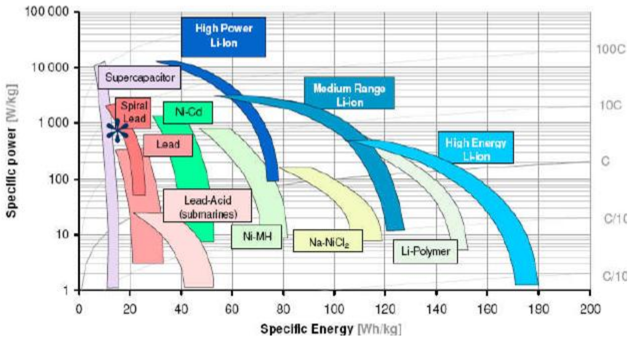

***Figure 3** – Energy density of different batteries*

Over the past decade, Li-ion batteries have taken a market dominant position, replacing less energy dense nickel metal hydride batteries. However, in spite of the several advantage of Li ion technology for its use in hybrid and electric vehicles, there are still different technological barriers to overcome and improve, such as the performance of the battery, its life, their recyclability, cost and safety.

The most suitable battery type is one that contains a large amount of energy in a small package, light weight and safety. This is found in the lithium polymer battery (LPB) which uses a solid polymer electrolyte (SPE). Lithium polymer batteries have the same common electrochemistry as conventional lithium ion batteries. They have a lithiated oxide cathode and a carbonaceous anode held together in a binder matrix of a polymer and coated and/or laminated to a current collector grid. However, they contain a highly porous separator, which converts to a gel when a minimum amount of electrolyte is added to operate the cell.

IV. PROPELLER

One of the most important issue that influence propulsion characteristics is the propeller. There are several theories for aerodynamic design of propellers, for example: ideal propeller theory, vortex propeller theory [1], blade element theory, disk theory, thin lifting surface theory. These theories differ from each other by resulting precision and computational effort. From practical point of view a satisfactory result gives propeller blade theory proposed by Baskin [2].

Propeller for electric engine has several particularities. Because the operation of battery and electric engine is relative quiet the main source of noise will be propeller. Therefore is desirable to minimize the tip speed of propeller blade. On the Figure 2 is depicted engine efficiency and torque vs. rpm. Electric engine provides especially high torque at low speed approximately 1800 rpm in comparison with classical combustion engine. It can be seen that also in range from 1400 rpm to 2000 rpm the efficiency of the engine can be over 93%. In the category of light aircrafts the usual diameter range for propellers is from 1,7 m to 1,8 m which results in tip speeds up to 200 m/s and tip Mach number 0,6. With proper airfoil distribution along blade radius and blade twist modification in the root area according Šajdakov [4] quiet and efficient propeller operation can be achieved without need extra gearbox for rpm reduction.

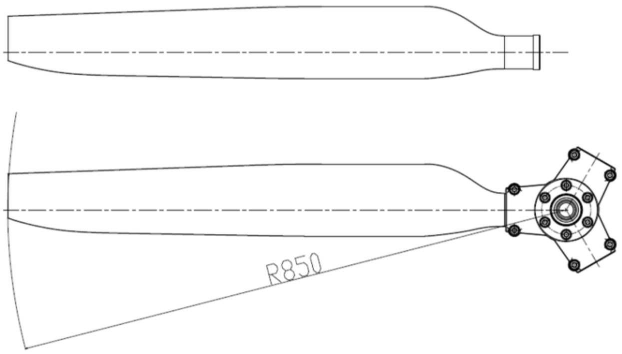

Figure 4 *– Typical blade geometry with propeller hub*

BLADE DESIGN

Today's technologies allow creating precision CAD model of propeller blade according aerodynamic and structural computations. This CAD model is processed on CAM program and final positive model of propeller blade from artificial wood is machined on milling machine (see Figure 5).

Figure 5 *– Positive model of propeller blade*

From this positive blade model the production mould is made. After the mould is prepared the composite propeller blades can be manufactured.

Figure 6 *– Composite propeller blade*

Modern composite materials allow achievement of optimal blade geometry with low relative blade thickness which positive affect propeller noise.

Figure 7 *– Propeller with electric engine in laboratory*

Final fixed-pitch propeller for VUT-051 RAY aircraft in laboratory is depicted on Figure 7. The ground and flight tests of this propulsion unit will begin soon. The main goal of these tests will be verification of the calculated propulsion characteristics of whole propulsion chain from battery to propeller.

V. CONCLUSION

The article describes main steps in propeller design for electric powered aircrafts. The main importance is given to decrease of propeller rpm in order decreasing of propeller noise. Further investigation will be performed after flight tests of VUT-051 RAY electric powered aircraft.

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THE SOFTWARE ENVIRONMENT FOR OPTIMIZATION AND ANALYSIS OF PROPELLERS

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***Abstract –The A*rticle describes the developed environment for the optimization and analysis of propellers. Procedures for the design aerodynamically optimal shape of the blade sand performance analysis are the first part of the environment. The procedure for propeller noise analysis is another part of the developed environment.**

Key words – efficiency, FWH, propeller, noise, optimization

I. INTRODUCTION

Propellers are an important part of the airplane propulsion system. With increasing ecological and economic demands, it is important to combine different analytical and design procedures.

Aerodynamic efficiency and low noise generated by aircraft propellers are important criteria for the operation of the airplane.

The development environment is described seeks to bring together tools for optimal aerodynamic design propellers with respect to the highest possible efficiency analysis of propellers for the various flight regimes and the possibility of analysing propeller noise.

Solution isoperimetric problem of variational calculus is used to design the shape of the blades of maximum efficiency. Lifting line theory and inverse problems of vortex theory are included for inverse aerodynamic analysis of propellers.

Compact formulations FWH equation is used to determine the noise analysis.

II. GENERAL DESCRIPTION OF THE SOFTWARE ENVIRONMENT FOR OPTIMIZATION AND ANALYSIS OF PROPELLERS

The Python programming language was chosen to produce a software environment. The presence of mathematical libraries, the possibility of parallel computing and programming simplicity block are its main advantages.

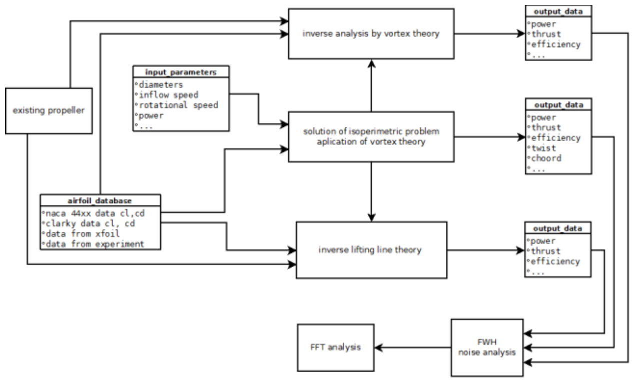

Figure 1 – General flowchart description

The environment now allows the aerodynamic analysis of existing propeller and design the optimal shape of the propeller blades. Computed data can be further used for the analysis of propeller noise. Parts of the block diagram represents a separate executable programs written in Python. Database aerodynamic of airfoil data is also included here. Parts of the block diagram including the theory are discussed in the following chapters.

III. AERODYNAMICS PROPELLER OPTIMIZATION AND ANALYSIS

SOLUTION OF ISOPERIMETRIC PROBLEM AND ITS APPLICATION FOR OPTIMAL BLADE SHAPE

This procedure is described in Brož [01] and El'sgol'c[02]. The task is to the design blade propeller. The shape of propeller blade is designed to have the best efficiency for one flight regime. The efficiency is defined by formula:

$$\eta = \frac{V_{oo} \cdot T}{N} \qquad (01)$$

For to find a solution of the isoperimetric problem, the task can be simply formulated as follows: find a closed flat curve of a given perimeter which encloses the largest area. The next formulation is used in application for optimization process : There are two given functions $F(x, y, y')$ and $\Phi(x, y, y')$ and task is: find a flat curve for which functional

$G=\int_a^b \Phi(x,y,y')dx$ gets value of constant G and at the same time it leads to extreme of functional $I=\int_a^b F(x,y,y')dx$. The problem can be reduced in $H=\int_a^b [F(x,y,y')+\lambda\Phi(x,y,y')]dx$. The solution of functional corresponds with Euler differential equation $F'_y-\frac{d}{dx}F'_{y'}=0$.

The function F can be thrust $\bar{T}(\bar{r},\bar{\Gamma},\bar{\Gamma}')$ or $\bar{N}(\bar{r},\bar{\Gamma},\bar{\Gamma}')$ in the same way like the function Φ can be thrust or power. These functions represent distribution of thrust coefficient or power coefficient along the propeller blade.

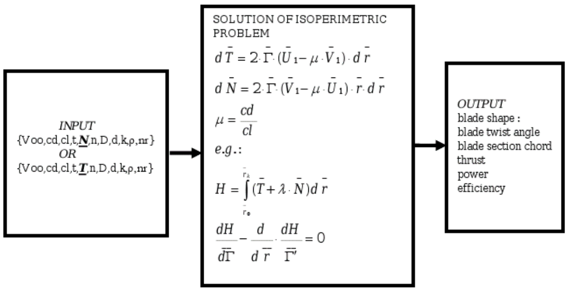

Figure 2 *– Flowchart of isoperimetric problem solution*

INVERSE ANALYSIS BY VORTEX THEORY

The procedure is described in Baskin [03], Alexandrov[04] and Švéda [05]. The procedure is based on solution of circulation equation (02) in prescribed blade section.

$$\left(\Gamma=\frac{1}{2}\cdot lift_{coef}\cdot choord\cdot w\_absolute\right)_{section} \quad (02)$$

LIFTING LINE PROPELLER ANALYSIS

The procedure is described in Baskin [03] and Alexandrov [04]. The theory is based on the assumption swirl system in the shape of vortices. It is possible to calculate the induced velocity induced by each faith. The propeller blade is divided into a few segments along radial direction. Induced velocities are computed on each radial station by application and solution of Biot - Savart Law.

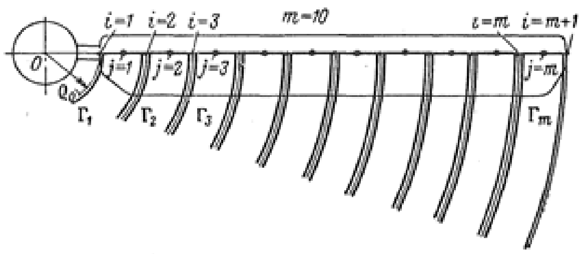

Figure 2 *– Figure description figure description figure description*

The basics procedure equations:

$$\bar{v}=\sum_{i=1}^{m} v_{ij}\cdot\Gamma_i\,(j=1,2,...,m...number\_of\_radial\_segments) \quad (03)$$

The contribution at each radial control points is computed by integration equations (04) and (05) from 0 to infinity.

$$v_{ij}=\frac{1}{4\cdot\pi}\sum_{i=1}^{k}\int_0^{\infty}\left[P_{ij}(n,\vartheta)-P_{i+1\,j}(n,\vartheta)\right]d\vartheta \quad (04)$$

$$P_{ij}(n,\vartheta)=\frac{\bar{\rho}_i^{\,2}-\bar{\rho}_i\cdot r_j\cdot\cos(\delta_n-\vartheta)}{\left[\bar{V}^2\cdot\vartheta^2+\bar{\rho}_i^{\,2}+r_j^{\,2}-2\cdot\bar{\rho}_i\cdot r_j\cdot\cos(\delta_n-\vartheta)\right]^{3/2}} \quad (05)$$

IV. PROPELLER NOISE ANALYSIS

Ffowcs-Williams Hawgkigns (FWH) equation is used for propeller noise analysis. There is a linear form of FWH equation Farassat [06], Magliozi [07].

$$\nabla^2 p-\frac{1}{c}\frac{\partial^2 p}{\partial x_i^2}=-\frac{\partial}{\partial t}\{\rho_0\cdot v_n\cdot|\nabla f|\cdot\delta(f)\}+\frac{\partial}{\partial x_i}\{l_i\cdot|\nabla f|\cdot\delta(f)\} \quad (06)$$

The left side of equation represents linear wave operator, p is acoustic pressure. The right side contains noise source terms resulting from surface moving. ρ_0 is ambient density, c is ambient speed of sound, v_n is the local velocity of the surface normal to itself, δ(f) is the Dirac delta function, x_i is the observer position and l_i is the i_{th} component of the surface force.

THE COMPACT SOURCE FORMULAS

For propeller noise analysis are derived in Succi [08] compact form of FWH equation. In this application is propeller blade divided into small segments, compact noise source. Each segment has its own force vectors. The final noise is obtained by summing over all noise source contributions. This form of FWH equation is often used because of its simply programming simplicity and clarity. The basic division of the compact source formulas has two main part. Thickness and loading term. The thickness term represents the effect of the blades parting the air. The second term of this form represents the action of the blade forces on the air and is divided on far – field and near – field members.

$$\Delta p(\vec{x},t)=\Delta p_{Thick}(\vec{x},t)+\Delta p_{Loading}(\vec{x},t) \quad (07)$$

$$4\pi p'(x,t)=\left[\sum_k \frac{1}{c}\frac{1}{|1-M_r|}\frac{\partial}{\partial\tau}\left(\frac{L_{ki}\vec{r}_i}{|1-M_r|}\right)+\frac{L_{ki}\vec{r}_i}{r^2|1-M_r|}\right]_{ret}$$

$$+\sum_k\left[\frac{\rho_0\psi_k}{|1-M_r|}\frac{\partial}{\partial\tau}\left(\left(\frac{1}{|1-M_r|}\right)\frac{\partial}{\partial\tau}\left(\frac{1}{r|1-M_r|}\right)\right)\right]_{ret}$$

(08)

The implementation of compact source formulas

The program structure for propeller noise analysis is in detail described in Farassat [06] and is programmed in the same way.

The following information are need for running of the program. Geometric data :

a) blade hub and tip radius, blade chord, thickness and twist distribution.

b) blade section distribution as function of radial coordinate

c) observer mode of motion, stationary or moving observer

Aerodynamics data:

blade loading or pressure distribution

Operating data:

propeller RPM and forward speed

The propeller blade is divided in to a few segments in accordance with application of compact formula. The number of elements (noise source) can be changed as necessary. The blade is replaced by number of points each with unique force vector and volume. The force vectors are obtained from propeller performance analysis. In this case, the loading data are obtained from blade element theory or lifting line theory.

After geometrical procedure, the second procedure the calculation of the noise source pressure signature. There is specified observer position at observer time t. In this application the observer position is stationary through the time. For the specified observer time, there is emission time for each noise source which is calculated by iterative scheme. In this case is used Brent method for solution of retarded time equation. At this retarded time, the contribution of a particular noise source is evaluated exactly according to equations (07). The summation of all blade noise source yields to the pressure signature at observer time.

The program is programmed in Python language. There are used Python library Numpy, Scipy and Matplotlib. This libraries provide simply and effective output and input data exchange, numerical tools for solution of nonlinear equation of retarded time and output graph form. The equation are implemented in vector form.

After evaluation of signal there is used FFT algorithm which is implemented in Python. Afterwards there is possibility to use different filter e.g. A - weighted filter.

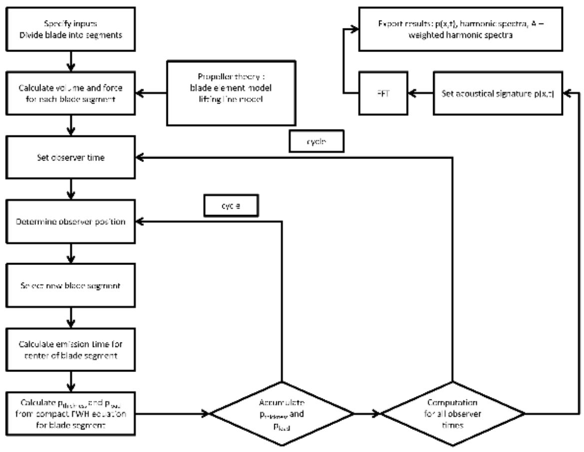

Figure 3 *– Figure description figure description figure description*

V. An example demonstrating an application of programing environment

For propeller is used inverse aerodynamics analysis by vortex theory.

Two-blade propeller with squared tip is analysed for ISA 0 m.

Propeller parameters.

Rev_per_min = 2100 ren/sec

Thrust = 1570 N

Power = 100000 W

D = 2.03 m

V_oo = 54 m/s

ClarkY sectional data

Propeller geometric data are taken from [09].

Noise analysis is performed only for far-field member of the FWH equation. Propeller blade is covered with noise sources in the radial and chord-wise directions. Flight is 50 m above the observer in normal direction. On Figure 4 and Figure 5 are presented results from noise analysis.

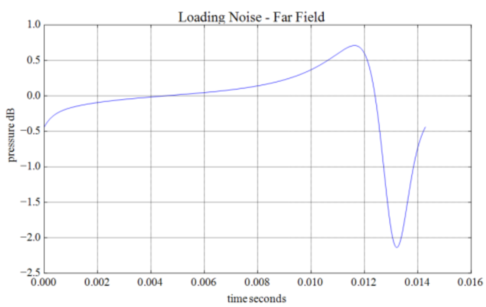

Figure 4 *– Pressure time signature*

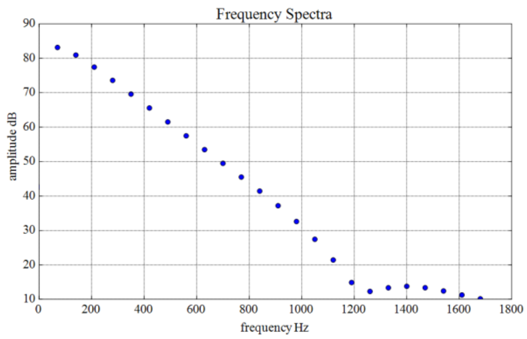

Figure 5 *– Spectral analysis*

VI. Conclusion

This paper presents a software environment for analysis and optimization of aircraft propellers. Currently, the environment enables the design propeller with optimum distribution of circulation and inverse analysis of propeller performance fo selected flight level. Next part of software environment, noise analysis procedure, was tested on theoretical example. At present,it will be necessary to further test thenoise calculation and comparing the results with experimental measurement. Software environment will be further developed and complemented by CFD analysis.

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OVERVIEW OF UNMANNED AERIAL SYSTEMS DEVELOPED AT THE INSTITUTE OF AEROSPACE ENGINEERING

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Abstract *– Institute of Aerospace Engineering at Brno University of Technology is participating actively on the development and operation of unmanned aerial systems. In the paper, brief overview of recent realized projects is given along with their technical details and lessons learned during the development.*

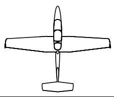
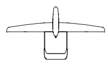
Key words – Unmanned Aerial System, UAV, UAS, autonomous flight, autopilot.

I. INTRODUCTION

The history of unmanned systems in Brno spans back to the beginning of 1980s, when several teams were concerned with development of what later became the Sojka project ([34], [25]). However the modern history of Unmanned Aerial Systems (UAS) at the Institute of Aerospace Engineering (IAE) starts around the year 2001, when IAE participated in the 5FP European Commission funded project UAVNET [2], joining 15 European research and academic institutions. Following participation in the project, proposal of IAE's own UAS has been formulated and thereby VUT 001 Marabu project has been born in 2006 [29].

During the course of the project it became apparent that experience needs to be gained with autonomous operation, preferably taking advantage of a less complex platform. Hence, VUT 700 Specto was designed and built. However, considerable amount of effort and financial resources has been invested into this airframe, making it still too valuable for first autopilot familiarisation. Yet simpler platform was therefore devised, VUT 710 flying wing aircraft. With this platform, Procerus Kestrel [21] autopilot and later on ArduPilotMega [6] were succesfully integrated and fully autonomous operation has been demonstrated. Following this success, experience gained is being exploited during operation of more capable airframes, such as VUT 720 or the original VUT 700 Specto. Brief overview of the main airframe parameters of UAVs developed at IAE to date is presented in **Table 1**.

Table 1 *Comparison of the basic UAS parameters*

	VUT 001 	VUT 700 	VUT 720 	VUT 710 
Span	9.9 m	4.2 m	2.6 m	1.2 m
Length	7.1 m	2.3 m	1.3 m	0.6 m
m_{TOW}	600 kg	20 kg	2.2 kg	1 kg
v_C	160 km/h	125 km/h	60 km/h	44 km/h
Endurance	7 hrs	5 hrs	1 hr	0.5 hr
Power	58 000 W	3 000 W	360 W	200 W
Payload	80 kg	5 kg	0.6 kg	0.2 kg
Payload description	various	autopilot SEDAQ cameras radar etc	autopilot cameras video TX	autopilot
Future	OPAV	sense and avoid dev.	aerial imaging	autopilot test bed
Based on	own develop.	own develop.	Multiplex Cularis	Telink Tornado

Apart from these physically developed UAVs, constant attention is being paid to the sector, typically in a form of student theses that either explore the current limitations of legislation [1] and UAS integration requirements ([3, 17]), or enhance the knowledge base of the currently available types ([20], [5], [10]). Some take advantage of these comparative studies and extend them into design of a new vehicle [15]. In this way, students are encouraged to keep in touch with this dramatically evolving branch of aviation.

II. VUT001 MARABU

The Marabu aircraft was conceived by prof. Antonín Píštěk in the wake of the UAVNET initiative, with the project being started officially in the year 2006. The original idea of the aircraft was to facilitate UAS development and operation in non-segregated airspace in an environment where regulatory base for civil unmanned aircraft is not established. Hence, the aircraft was designed as an Optionally Piloted Air Vehicle (OPAV) ([11], [12]). Such a concept is capable of performing a normal piloted flight with a pilot on board. Pilot presence on board makes OPAV status fully legal even if the pilot does not participate at the actual control of the aircraft ([31], [32], [13]). Hence, OPAV is ideally suited for integration of new avionics equipment, its testing and certification – with the pilot always being readily available on board to step in should the situation require it. The OPAV concept also brings the possibility of gradual transition into the fully autonomous operation mode as the new avionics modules and functionalities are being developed or acquired during the course of the project.

The aims of the Marabu project could be described as follows:

- Create a platform for instrument development and integration testing
- Enable smooth transition to More Electric Aircraft, so that fully autonomous operation can be achieved later on without any problems
- Develop a dedicated flight data acquisition system in order to characterize the airframe thoroughly
- Develop a sense and avoid capability test platform – hence the nose of the aircraft was designed to provide unobscured front view.

Figure 1 *VUT 001 Marabu during flight measurement*

The aircraft has been in development since 2006 at IAE, serving as a brilliant hands-on experience for the students of the institute ([23], [28]). The maiden flight took place on 29/04/2010. The aircraft successfully passed all the flight tests, proving fit for the intended purpose. The aircraft is going to be succeeded by a twin tail-boom derivative VUT 081 Kondor [16]. In the meantime, several derivatives have been proposed and evaluated ([9], [30], [24], [4], [19] among others), two of them being promoted into the project phase:the first one featuring newly developed turbo propeller engine (VUT 071 Turbo), the second one being a fully electrically propelled model (VUT 051 Ray). All of the aforementioned aircraft are currently under development and are foreseen to fly in the coming months.

III. VUT 700 SPECTO

The Specto airplane was conceived as a smaller and cheaper test bed for measurement system and avionics integration. It was designed and built by students of IAE in the period of 2007 – 2009 ([7], [36]). The maiden flight took place on 22/01/2009 at LKCM Medlanky airport. The aircraft is depicted in **Figure 2**.

Figure 2 *VUT 700 Specto flight testing*

Procerus Kestrel autopilot has been acquired in order to be implemented into Specto aircraft to gain experience with autonomous aircraft operation. However, the baseline autopilot allows only for four channels to be connected which is inappropriate for the Specto airframe being equipped with 8 servo channels which need to be controlled by the autopilot. Another consideration was the amount of money and labour invested into the aircraft during the development, hindering the implementation process in a fear that tuning of the autopilot might crash the aircraft. Due to the aforementioned reasons, simple dedicated test bed was built for autopilot as described in section IV.

In the course of the project, camera gimbal was installed to the front part of the fuselage. Paired with Inertial Measurement Unit enhanced video goggles on the pilot's head, the system is replicating the operator's movement and therefore provides telepresence on the board of the aircraft. The system was developed in cooperation with the Faculty of Electrical Engineering and Communication, Brno University of Technology [18].

Dedicated parachute recovery system was designed for the Specto aircraft in order to increase the safety of its operation and facilitate its integration into the non-segregated airspace [27]. It has not been manufactured and integrated yet, however.

Specto features measurement system called SEDAQ (Sensor Data Acquisition Unit), which was developed in cooperation of IAE with Faculty of Information Technology [8]. The measurement system is intended to gather data in-flight, enabling to characterize the aircraft in terms of handling properties, stability derivatives, performance etc. These data are vital for creation of virtual dynamic model of the aircraft, which could be used during Hardware In the Loop (HIL) autopilot tuning, for aircraft simulator - pilot training and other applications.

To accompany the measurement system, dedicated angle of attack pitot-static probe was designed and manufactured at IAE as depicted in **Figure 3**. This probe enables characterization of the aircraft reaction to gusts. Unfortunately, the piston engine powered Specto airframe proved to generate significant vibrations, which prevented acquisition of high quality data. Therefore, special low-vibration electric version of the aircraft was developed.

Figure 3 *In-house developed angle of attack measurement probe*

VUT 701 ESPECTO

As described above, main motivation for this variation of Specto aircraft was to develop a stable, low-vibration platform for high quality flight measurement data acquisition. Another benefit of the electric powered aircraft is its easier integration with autopilot and decreased pre-flight preparation complexity.

Again, the aircraft was completely designed and built by IAE students during the 2011-2013 period. Consequently, new generation of SEDAQ system was developed, featuring 100Hz sampling rate, enhanced sensor integration by means of serial connection and increased Electromagnetic Compatibility. The main SEDAQ data acquisition unit is depicted in **Figure 4**.

Figure 4 *SEDAQ Main unit*

Maiden flight took place at Czech Heaven model airport near Ivancice on 14/04/2013. It was followed by a flight measurement campaign, featuring both RC-piloted flights and autopilot-stabilized flights. The autopilot selected for integration was the ArduPilotMega 2.5+ [6], primarily for its readily available 8 channels and ease of integration, which enables the pilot to control certain channels manually, while having others stabilized by autopilot. This feature proved very useful during the measurements.

Subsequently, the flight data were processed and dynamic model was created [35], identifying the airframe's main handling properties and performance parameters. These were fed into RC simulator (**Figure 5**), which enables quicker adaption to the airframe for new pilots. Sample of the processed data is given in Figure 6.

Figure 5 *VUT 700 Specto model in RC simulator*

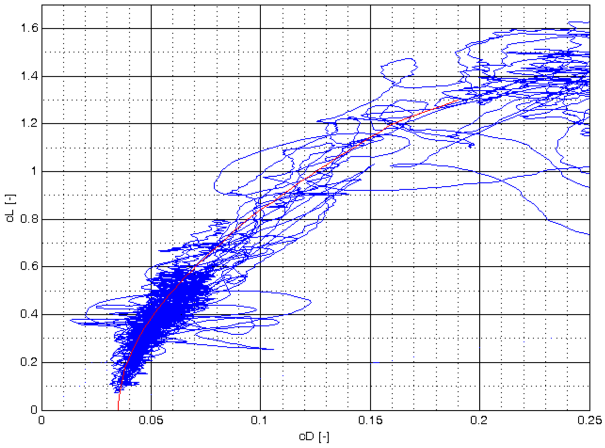


Figure 6 Drag polar curve as evaluated from the dynamic measurement

The aircraft is foreseen to be used for further tuning of the autopilot PID loops, subsequently to be used for autonomous flight validation for this category of aircraft in the coming months. It is also ideal for tests of Sense and Avoid system, Synthetic Aperture Radar, computer vision aided navigation and other subsystems, being developed by IAE's partners.

New generation of Specto aircraft is also foreseen to be developed, featuring streamlined fuselage to improve the aerodynamic performance and enable operation from unpaved runways by directly supporting catapult launch and skid landing.

IV. VUT 710 FLYING WING

Following the acquisition of Kestrel autopilot, it became apparent that simple, cheap platform is needed to familiarise with the new technology, without the risk of destroying larger aircraft such as Specto. The autopilot manufacturer offers tailless aircraft for this purpose [22], the concept was therefore kept the same. The aircraft was built based on commercially-available airframe [33], keeping the cost of the whole setup under 200 EUR. This way, the aircraft itself has much lower value than the autopilot itself. Furthermore, the aircraft is built from glass-fibre reinforced Extruded PolyPropylene (EPP), proved to be virtually indestructible and therefore widely used for RC combat aircraft. This renders the airframe ideal for tuning of potentially hazardous manoeuvres, such as autonomous take-off and landing.

The aircraft was built by students of IAE during 2011, initially being flown in fully RC-piloted mode, switching towards the autonomous autopilot operation in the first half of 2012.

Figure 7 *Camera installed on VUT 710*

Once fully autonomous take-off, flight (including waypoint navigation) and landing was mastered, the aircraft was equipped with GoPro HD Hero 2 outdoor camera (**Figure 7**) and aerial surveying tasks were performed. Example of a 3D model processed from approximately 300 aerial images is given in **Figure 8**.

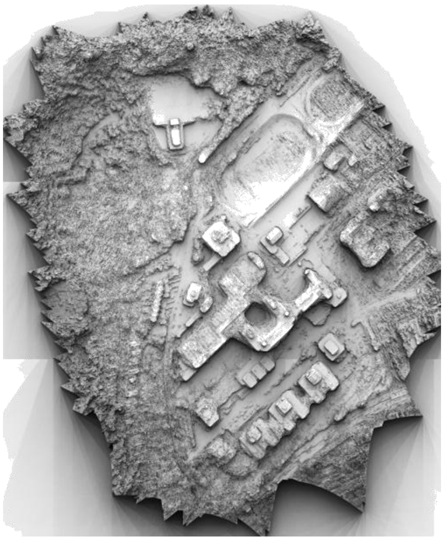


Figure 8 *3D model of the Brno University of Technology campus as mapped with VUT 710*

Despite the success with aerial imaging, the installed camera proved to be inadequate for more precise photogrammetric tasks. At the same time, the airframe is not capable of carrying bigger/heavier camera.

VUT 711 Flying Wing 2

Following the promising operation of VUT710 with Kestrel autopilot, the airframe has been rebuilt and strengthened during 1Q/2013 and fitted with a new generation of autopilot, ArduPilotMega2.5+ [6]. Apart from the low price, the biggest advantage of this system is the open-source architecture, enabling IAE to directly manipulate with the autopilot code, implement new features etc. It also allows for smooth integration into higher-level navigation and command systems.

The new autopilot proved to be very capable and in many aspects more suited to IAE’s needs than the Kestrel system. First of all the system can be integrated into the airframe very smoothly, with gradual increase of the autonomy in time. It also preserves the original RC control link for the master command of the aircraft, enabling instantaneous switch to fully manual operation in case of emergency. This contributes greatly to the operator’s comfort and hence to the safety of the operation.

The main objective of the airframe – familiarisation with the autopilot – was achieved and the autopilot could therefore be moved into larger aircraft. However during the operation of VUT 711 it became apparent that this size of airframe is much better suited to many use cases than VUT 700 Specto or other bigger platforms. VUT 711 is able to operate from the most constrained spaces, such as forest clearing, it can be hand-launched, it does not require any assembly or pre-flight procedures etc. Therefore, it proved to be very operative and is the airframe of choice for several IAE’s partners.

Figure 9 *VUT 711 after autonomous landing on snow*

The obvious limitations of the airframe in the payload capacity however spurred up plans to build more capable aircraft (that could carry e.g. a reasonable camera), while maintaining the inherent toughness of EPP structure, and therefore the great operation flexibility. Such an airframe is described in section V.

Currently the VUT 711 airframe continues to serve as a test bed for new autopilot features implementation, tuning, etc. Furthermore, it is being used for testing of direct integration into emergency response team command system. It is also foreseen to take part in formation-flight research.

V. VUT 720

To date, VUT 720 is the latest addition to the small UAV fleet at IAE. It has been conceived based on the experience with VUT 711 – it aims to preserve its brilliant toughness and ease of operation, while increasing the payload capacity. The payload requirements based on discussion with IAE’s partners consisted of small compact camera capable of photogrammetry aerial imaging and on-line video downlink for aerial surveillance of e.g. forest fires. The actual payload specification consists of:

- GoPro HD Hero 3 Black edition camera + ImmersionRC 5.8GHz transmitter. The camera is capable to simultaneously transmit SD video and store the footage in up to 4K resolution. It can also take up to 12Mpix still images based on various time-lapse schemes.
- Canon PowerShot S100 compact camera with alternative CHDK firmware [14]. The camera is equipped with built-in GPS receiver, therefore all images are automatically geo-referenced. Further synchronization with autopilot attitude is possible.

Figure 10 *VUT 720 side camera view - fire brigade training*

The other objective of the VUT 720 is to serve as a test bed for VUT 700 Specto autopilot integration, featuring the same control surface setup and number of controlled channels.The aircraft is based on a commercial platform [26] in order to keep the price to the minimum.

Figure 11 *VUT 720 maiden flight*

The aircraft has been built at IAE during first half of 2013 and the maiden flight took place on 01/05/2013 at LKCM Medlanky airport.Subsequently autopilot parameters were tuned and fully autonomous operation was achieved. Since then, on-line video streaming was demonstrated as well as detailed aerial imaging fit for photogrammetry applications. The aircraft was deployed e.g. during a forest fire training and proves to be very perspective platform for many mission types, foremost those involving aerial mapping and reconnaissance.

VI. Ground Segment

The ground segment configuration depends on the respective mission, however typically consists of remote control system, mission planning station and video downlink display.The components currently in use at IAE are:

- Graupner MC-22s radio control system
- Panasonic Toughbook CF-19 rugged notebook
- 8” outdoor-viewable LCD + diversity video receiver

Wireless link with the airborne segment consists of:

- RC command signal + RC telemetry based on JETI Duplex 2.4EX system operating at 2.4GHz
- Autopilot telemetry system: xBeerunning at 2.4GHz or Microhard n920 modem operating at 868MHz
- Video downlink: ImmersionRC diversity system running at 5.8GHz

There are two different 2.4GHz systems operating simultaneously, however no deterioration of the signal quality or range has been observed. All the telemetry data are being stored during flight for post-flight analysis both at the ground station and on the board. Video stream can be routed to various external devices for higher-level system integration and storage.

No standardized ground segment container has been devised so far, keeping the setup flexible and modular. However, ground segment setup times could be decreased by integration into a single case, therefore it is foreseen that this step is going to be taken in the near future.

VII. Conclusion

During the course of UAS development at IAE, the system complexity kept decreasing, literally test beds for test beds were created, in order to mitigate potential hazards connected to autopilot integration by decreasing the overall value of the airframes. However, the lowest point has already been reached – the autopilot has been successfully integrated into simple aircraft, enabling IAE to perform fully autonomous operation including take-off and landing. Following this milestone, the autopilot technology is being integrated into more and more elaborate airframes, increasing value of the airborne systems for the end users. UASs are actually becoming useful in real-life use-cases.

Currently IAE is able to autonomously operate aircraft with up to 20kg m_{TOW} with endurance up to several hours. The payload possibilities range from HD video cameras with live video streaming through photogrammetry-fit digital cameras up to Infra-Red imaging systems, stabilized gimbals and various sensors depending on the customer preference.

The step that remains to be taken is to certify all the aircraft in frame of the newly issued Appendix X to L2 regulation. In the research domain, challenges to tackle in the near future are sense and avoid capability, formation flight and others, paving the way towards non-segregated airspace integration of civil UAVs.

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FREE-FORM DEFORMATION PARAMETERIZATION FOR AERODYNAMIC SHAPE OPTIMIZATION

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Abstract *–An Activity in the European project CEDESA focused on aerodynamic shape optimization in the context of aircraft design is the main subject of cooperation between Swedish defense research institute FOI and Brno University of Technology. We present here developed optimization procedure consisting of Free-Form Deformation parameterization method and gradient-based optimization algorithms,tested in aerodynamic shape optimization of transonic swept wing.*

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Key words – FFD, Aerodynamic shape optimization, CFD, gradient-based, adjoint.

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I. INTRODUCTION

Current global situation highlight the role of the optimization procedures. The competition on the markets forces the manufacturers to accelerate the design phase of new products. It will be very hard if not impossible to fulfil the rising demands on development and operational cost reductions without the help of modern optimization tools. That is especially true in the aircraft industry, where is the use of modern optimizations tools becoming standard.

One of the key steps in optimization process is parameterization of the geometry. Parameterization defines possible object shapes and shape changes by a set of parameters which are used as design variables during the optimization process. The number of optimization parameters has major influence on the computational time cost. It is crucial to have suitable parameterization for each specific task. Wrong parameterization can slow down the optimization process or even prevent the optimization algorithm from finding the optimum solution, since the parameterization could not be able to generate optimum shape. FFD parameterization method was chosen to deal with all of these problems.

II. FREE-FORM DEFORMATION PARAMETERIZATION

Originally introduce by Sederberg and Parry [1], the Free-Form Deformation (FFD) parameterization was developed for computer graphics, since then it has been widely used and modified in the computer animation industry. The advantages that the FFD brings into the field of object parameterization have caught attention of the aerodynamic optimization community. E.g. Samareh [2] and Andreoli, Janka and Desideri [3]used FFD in aircraft design optimization cases.

NURBS-based variant first published by Lamousin [4]algorithm treats the modelembedded in NURBS volume as rubber that can be stretched, compressed, twisted, tapered or bent and yet preserve its topology that makes it well suited for handling of complex geometries, it also enables to deform only part of the domain of interest while the rest of the geometry remains intact and the transition between deformed and unreformed parts smooth.

FFD PARAMETERIZATION PROCEDURE:

The FFD parameterization procedure has four steps:

a.) Construction of the Parametric Lattice

b.) Embedding the object within the Lattice

c.) Deforming the Parametric Volume

d.) Evaluating the Effects of the Deformation

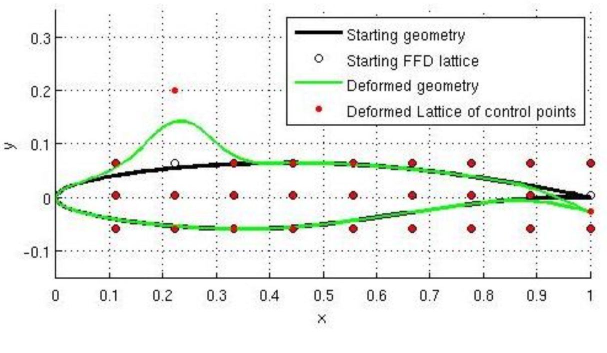

Figure 1 *–Demonstration of deformation of airfoil geometry*

a.) Construction of the Parametric Lattice

As described in Amoiralis and Nikolos [5] a lattice of control points is constructed around/in the object that should be deformed. This defines parametric coordinate system. Nodes of the lattice are used as control points to define NURBS volume that contains the object to be deformed. NURBS polynomials are defined in each lattice direction u, v, w. Constraints of polynomial degrees:

$$1 \le m \le b$$
$$1 \le p \le a$$
$$1 \le n \le c \tag{1}$$

Where p, m, n define degree of the basis polynomial function in corresponding direction, a+1, b+1, c+1 are numbers of the control points in each direction.

NURBS uses knot vectors, where:

$$\mathbf{U} = (u_0, u_1, ..., u_q), q = a + p + 1$$
$$\mathbf{V} = (u_0, u_1, ..., u_r), r = b + m + 1$$
$$\mathbf{W} = (u_0, u_1, ..., u_s), s = c + n + 1 \tag{2}$$

Values of U knot vector are calculated as:

$$u_i = \begin{pmatrix} 0 & 0 \le i \le p \\ i - p & p < i \le (q - p - 1) \\ q - 2.p & (q - p - 1) < i \le q \end{pmatrix} \tag{3}$$

and unified with range of x coordinates of parametric u coordinate. This knot vector has p multiple (same value) members at the beginning and at the end. V and W vectors are calculated similarly.

NURBS basis functions N are defined for every direction of the parametric volume. N for u direction is calculated with standard recursive formula.

$$N_{i,p}(u) = \frac{u - u_i}{u_{i+p} - u_i} N_{i,p-1}(u) + \frac{u_{1+p+1} - u}{u_{i+p+1} - u_{i+1}} N_{i+1,p-1}(u) \tag{4}$$

$$N_{i,0}(u) = \begin{pmatrix} 1 & u_i \le u < u_{i+1} \\ 0 & otherwise \end{pmatrix} \tag{5}$$

Where u is vector of coordinates of geometry (points) that is to be deformed (calculated one by one in loop), i is position in knot vector and u(i..) are coordinates in knot vector.

The Cartesian coordinates of a geometry points within the 3D volume with parametric coordinates u,v,w are calculated using

$$R(u,v,w) = \frac{\sum_{i=0}^{a}\sum_{j=0}^{b}\sum_{k=0}^{c} G_{ijk}.P_{ijk}.N_{i,p}.N_{j,m}.N_{k,n}}{\sum_{i=0}^{a}\sum_{j=0}^{b}\sum_{k=0}^{c} G_{ijk} N_{i,p}.N_{j,m}.N_{k,n}} \tag{6}$$

Where R is Cartesian coordinate vector of a point [u,v,w] in a parametric space, Pijk is vector of control points coordinates (xi, yi, zi,) in u direction and Gijk is matrix of weights.

b.) Embedding the object within the Lattice

The object to be deformed is described by set of Cartesian coordinates (x,y,z), to use FFD a corresponding parametric coordinates (u,v,w) have to be found.

The embedding step means that It is needed to find such parametric coordinates that the product R(u,v,w) will be equal or in specified tolerance to the Cartesian object coordinates. So an inverse problem needs to be solved in this step. Reliable secant method is used in our approach.

c.) Deforming the Parametric Volume

Is accomplished by deformation of the lattice of control points P_{ijk} or/and the weights G_{ijk} are modified.

d.) Evaluating the Effects of the Deformation

The deformed coordinates R(u,v,w) are calculated from the equation (6).

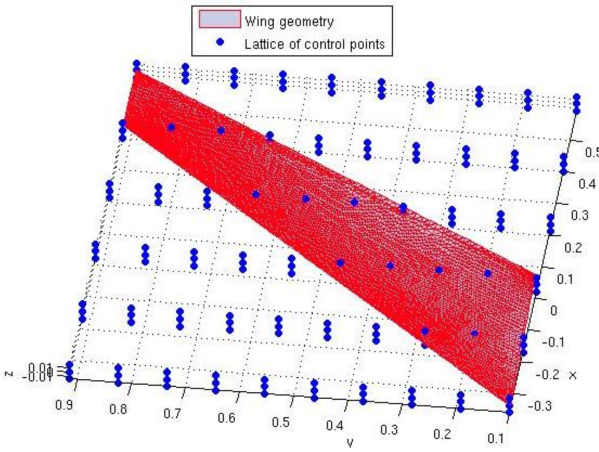

Figure 2 *–Example of parallelepiped FFD lattice of control point createdaroundasupersonicwingmesh*

Advantage of this method is that it enables deformations of whole object within the NURBS volume. For example wing surface can be deformed with its inner structure (spars, beams, fuel tank) and also with whole computational domain for flow simulation around it. All the deformations are smooth and the topology remains the same. An opportunity for future application of this method is in aeroelastic optimizations (FEM-CFD).

Most computational effort during FFD parameterization is in calculating the NURBS volume, which does not change in the optimization process and needs to be calculated only once. As a result, in the next optimization iteration the deformation of complete wing mesh could take only seconds, maybe minutes.

III. SHAPE OPTIMIZATION

BACKGROUND

Through decades the shapes of aircrafts or their parts were designed by experience and intuition of the engineers. Nowadays, a further improvement of the existing design focused on an aerodynamic improvement is getting harder. It is the use of optimization methods that could make the aircraft aerodynamics more effective. The aerodynamic shape optimization is able to expose the improvement which may not be revealed nor by the intuition neither by the experience.

In order to get the best possible results the well-defined optimization problem is a necessity. The problem definition consist of an objective function which is going to be minimized and the constraint functions or/and bounds on the optimization variables. The objective function can be formulated as a minimization of the drag, a maximization of the glide ratio (defined as a minimization of the inverse of glide ratio), etc. and this can be subjected to aerodynamic, geometric or structural constraints (a constant lift, a constant volume of an integrated fuel tank, etc.).

The optimization is always done for a specific design point, i.e. the flight conditions. This does not guarantee an improvement of design in the different flight conditions. In the worst case, it can worsen the design. Thus, a multipoint optimization can be performed. It means to optimize the objective function which has form:

$$\min_{X \in I} F(X) = \sum_{i=1}^{N} w_i \cdot c_{Di}(X)$$, where

$w_i$is weight of the i-th design point

The multipoint optimization is more time demanding, can struggle to converge to solution and most importantly the optimum solution may bring almost no improvement to the old design. Thus, the definition of optimization is the key of the success.

The problem can be solved by the various optimization methods, for example evolutionary algorithms, response surface methods, gradient-based methods, etc. In this paper, we are focused on the last mentioned, gradient-based methods.

GRADIENT CALCULATION

The gradient-based optimization algorithms require an evaluation of the gradient of the objective function and/or constraint functions with respect to the optimization variables. Since, gradient calculation increase the cost of optimization, it is of interest to calculate gradients efficiently and with sufficient accuracy. There are several methods for the gradient calculation. Each of them has its own pros and cons and choice depends on a current application. The main of numerical methods are:

- Finite difference approximation
- Complex-step derivative approximation
- Methods using differentiation
  - Algorithmic differentiation, also known as automatic differentiation
  - Hand differentiation: Jacobian derivation and adjoint method

An advantage of the finite difference gradient approximation is its ease of implementation. The cost of calculation can be independent on a number of function (for example in case of a CFD solution all aerodynamic forces are given at once), the cost grow with increasing number of optimization variables.A choose of step size is problematic, as well.

For an optimization with large number of the variables and a few functions the adjoint method is advantageous. The total cost of the gradient calculation is one flow solution plus one adjoint evaluation, for each function one adjoint solution is needed. Thus, thecost of this method grows with a number of functions, but is independent on a number of variables.

The adjoint approach is based on theory of optimal control for the systems described by the partial differential equations. Two methods could be used - continuous and discrete. In continuous approach, the adjoint problem and the formulation of the gradients are derived from the flow PDEs and then discretized. In the discrete approach, numerical calculations of the PDEs, cost and constraint functions are completed before the derivation of the adjoint problem.

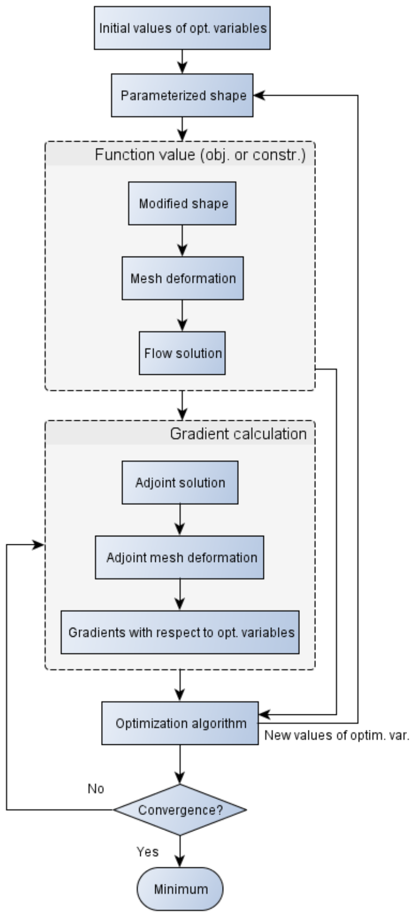

***Figure 3**- Adjoint optimization scheme*

IV. Wing optimization

Descriptions

The capabilities of Free-form Deformation parameterization was tested on an optimization of a highly swept transonic wing. The flow was governed by the Euler equations. The free stream properties are given in Table 2.

Table 2 - Free stream properties

Pressure	p_∞ [Pa]	101325
Temperature	T_∞ [K]	288.15
Mach number	M_∞ [-]	0.79
Angle of attack	α_∞ [-]	2.79

The geometry was parameterized by an orthogonal lattice of control points. In order to use the capabilities of parameterization as much as possible, the procedure of geometry fitting into lattice was used. The descriptions are given in 0. A summary of parameterization is given in Table 3. The middle row of control points in a root section was fixed in the initial position. The optimization variables were displacements of the control points in vertical direction (in direction of y axis).

Table 3 *- Parameterization description*

Number of control points in x, y and z direction	4, 3 and 8
NURBS degree in x, y and z direction	2, 1 and 2
Number of variables	92

The goal of the optimization was to minimize a wave drag, with constant lift and constant volume of a wingbox formed by the wing spars located in 33 and 66% of a local chord.

Thus, the optimization problem is defined:

$$\min_{X\in I} F(\boldsymbol{X}) = c_D(\boldsymbol{X}), \quad I \in [-1,-1],$$

subjected to:

$$g_1(\boldsymbol{X}) = c_L(\boldsymbol{X}) - c_L^0 = 0$$

$$g_2(\boldsymbol{X}) = V(\boldsymbol{X}) - V^0 = 0$$

The optimization algorithm used for solving was a conjugate gradient with nonlinear constraints, when the gradient of the objective function is reduced by projected gradients of the constraints. The gradients were calculated by adjoint of the flow using CFD code Edge [6] developed at our partner organization FOI. The same code was of course used as well to calculate the flow solution and thus evaluate the cost function value.

Results

The results of the test optimization problem show good usability of the FFD parameterization in the optimization. The final shapes of the sections listed in Figure 5, Figure 6 and Figure 7 proof an ability of the parameterization to create various changes along the span of the wing and in the chordwise direction, as well.

The drag coefficient was decreased by about 38%, while lift coefficient was kept constant. The resultant moment coefficient was increased, but there was not a constraint for it, therefore this is not a fault. A history of the objective and constraint functions is plotted in Figure 4.

Table 4 *- Aerodynamic force coefficients*

	C_D	C_L	C_m
Initial	0.0667	0.8509	-0.5104
Final	0.0411	0.8510	-0.5459
Difference	-38.4 %	0 %	-7 %

The Figure 8 to Figure 11 imply that a shock was weakened what led to a drag reduction.

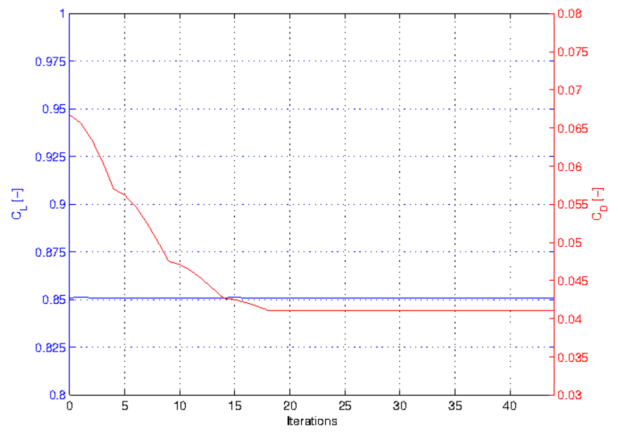

Figure 4*- Drag and lift coeficient history*

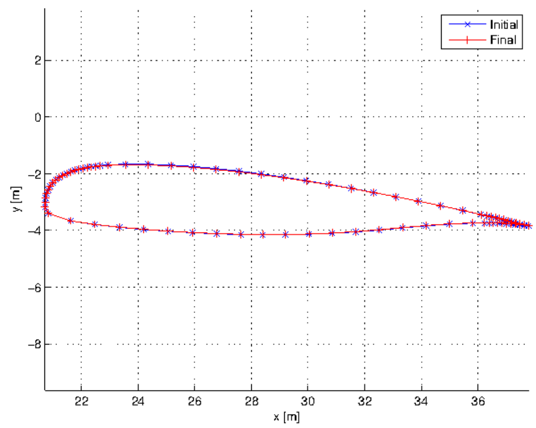

Figure 5 *- Shape of root section*

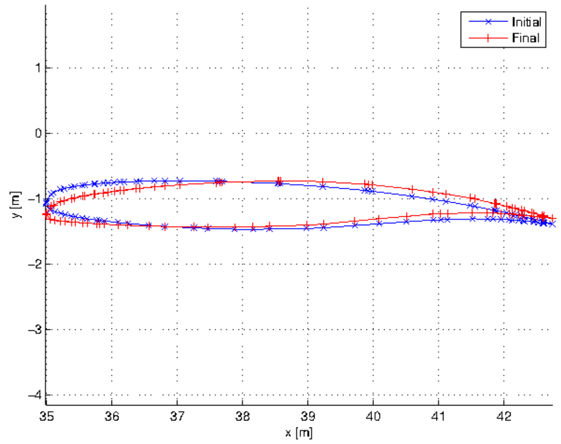

Figure 6 *- Shape of section between root and tip*

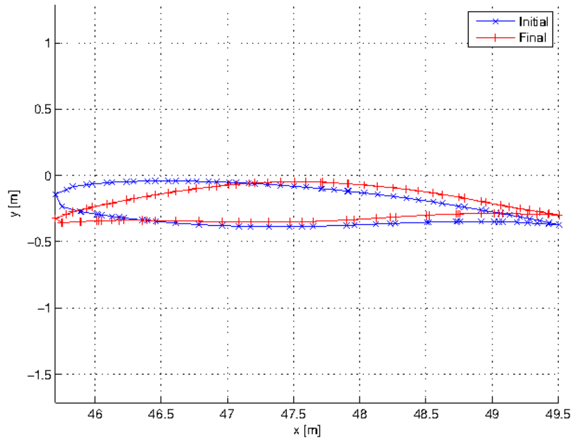

Figure 7 *- Shape of near tip section*

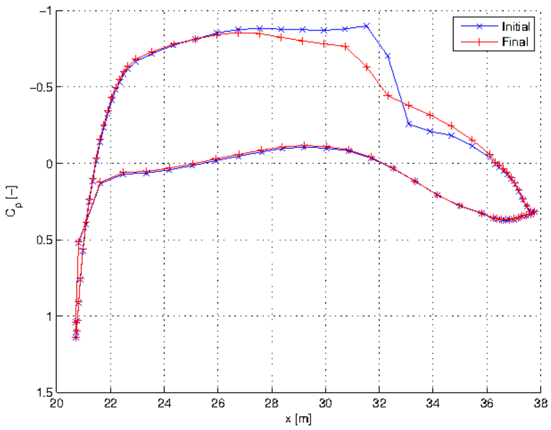

Figure 8 *- Pressure distribution in the root section*

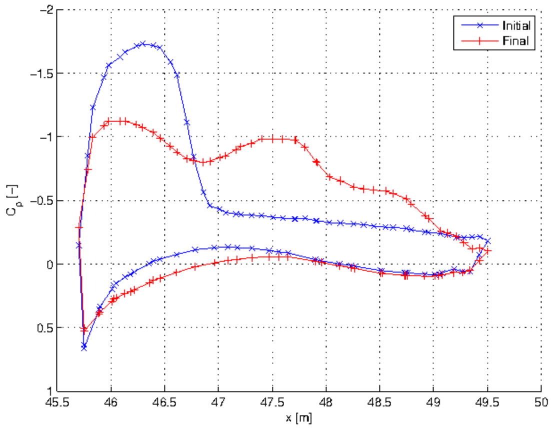

Figure 9 *- Pressure distribution in the near tip section*

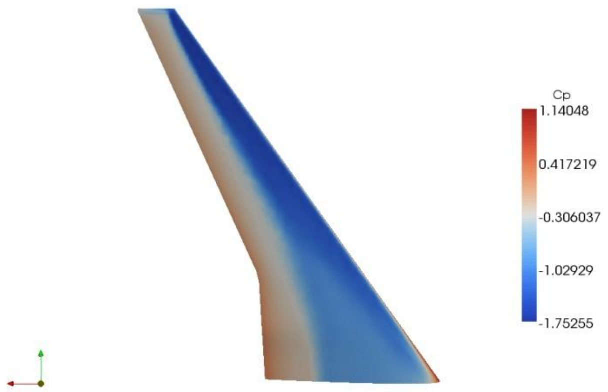

Figure 10 *– Initial spanwise pressure distribution*

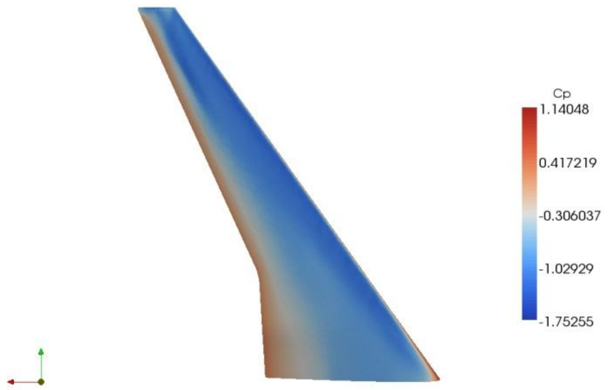

Figure 11 *- Final spanwise pressure distribution*

V. Conclusion

Developed optimization procedures proved to be useful in practical aerodynamic shape optimization tasks. The FFD parameterization is well suited of handling the geometry and in the combination with gradient-based optimization method capable of generating interesting improvements in aerodynamic design.

Further investigation of FFD parameterization and its modifications is currently being carried out in order to enable adaptivity of the FFD lattice of control points to the complex aircraft geometry.

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HUMAN FACTOR AND ITS ROLE WITHIN GROUND HANDLING SAFETY ISSUES

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Abstract *– As the traffic is constantly growing, apron safety is a very important and actual topic these days. Ground handling accidents cause huge losses of few billions to the airlines all over the world each year. However, most of these accidents are caused by human errors and it can be very easy to prevent them. The article provides the human factor questionnaire results which were collected from seven different ground handling companies in Netherlands. Moreover, it brings the safety regulations overview.*

Key words – safety, human factor, airports, case study.

I. INTRODUCTION

In the area of commercial aviation worldwide, airlines suffer high costs from damage resulting from ground-related occurrences. The Flight Safety Foundation (FSF) provided a report stating that 7 500 000 000 EUR a year are being spent because of ground accidents all over the world and these numbers are increasing every year. Apart from the economic consequences, increased safety risks are also of concern to the personnel involved.

Most of the errors are caused by human factor. It is a common knowledge that human factors may negatively influence the performance of operational personnel at work. Also, it is proved that proper attention to human factors can positively influence behaviour of personnel at work. This is considered as the manifestation of an organization's safety culture. In a positive safety culture, the human factors are acknowledged and training is provided in order to manage these human factors and preserve the safe organizational environment.

Safety culture of a group is the set of enduring values and attitudes regarding safety issues, share among the members of the group. It refers to the extent to which the members of the group are positively committed to safety; consistently evaluate safety related behaviour; are willing to communicate safety issues; are willing and able to adopt themselves when facing safety issues; and are continuously behaving so as to preserve and enhance safety.

II. GROUND HANDLING SAFETY REGULATIONS

First off, it is necessary to get to know with the regulatory framework of ground handling activities. There are various organizations creating this framework, hence there is wide bunch of the rules to be followed. In this section, the overview will be presented.

It is natural that safe operation during ground handling is desired by all parties involved. This is why the international ground handling regulations were introduced to aviation. However, these regulations are devoted just to airports and operators.

Ground operators are partially responsible for safe operation since JAR-OPS 1 regulations were established. According to that regulation procedures for ground handling staff were created and ground staffs have to be trained that no person will endanger the operation. Also each operator has to nominate a person who will be responsible for safety management and supervision of ground procedures. Other practices like flight safety programme, incident reporting system and accident prevention required by JAR-OPS 1 are more specifically described for some procedures like fuelling, pushback, towing and loading of the aircraft. JAR-OPS 1 regulations have to be signed by all operators responsible for handling aircraft and contract arrangements should include training of ground staff as well.

Airports, on the other hand, are also partially responsible for safe operation during ground handling as is stated in International Civil Aviation Organization (ICAO) Annex 14. This annex mainly concerns airport facilities but some operation procedures for ground handlers like driving on the apron are included. An overlap with JAR-OPS1 and Annex 14 is in procedures for fuelling while passengers are still on board of an aircraft.

ICAO Annex 14 – 1.4 requires states to evaluate and certify airports that are used for international operation according to the requirements of this Annex from 27th of November 2003. According to the Regeling Toezicht Luchtvaart (RTL - Aviation Supervision Regulations) in Netherlands RTL - Aviation Supervision Regulations is this certification done on a voluntary basis. Schiphol Airport was initially certified by RTL in 2004 and later in 2007 this certificate was extended for another three years.

Apron operators and safety regulators list can be seen in Table 1 (next page).

Table 1 *– Apron operators and regulators [Source: ACRP, Ramp Safety Practices]*

Organization	Shortcut	Standards	Description
Air Charter Safety Foundation	*ASCF*	ACSF Industry Audit Standard Operator Documents	Provides safety standards for ground handling and services
Air Transport Association	*ATA*	Recommended Guidelines for Preventing and Investigating Aircraft Ground Damage	Multiple documents including safety of ramp operation
Airport Council International	*ACI*	Airside Safety Handbook and Apron Markings and Signs Handbook	Set of guidelines for safety and markings managers
Australian Aviation Ground Safety Council	*AAGSC*	Ground safety practices and training material	Computer and video resources for standard practices of apron safety
Boeing	*Boeing*	Ramp Error Decision Aid (REDA) Users Guide	Structured process used to investigate errors made by ramp personnel
Civil Aviation Authority	*CAA*	CAP 642 Airside Safety Management	U.K. ramp operation and practices including risk analysis
Flight Safety Foundation	*FSF*	Ground Accident Prevention	e-tools on apron operation and practices
International Air Transport Association	*IATA*	IATA Safety Audit for Ground Operators (ISAGO) Airport Handling Manual (AHM	Field publication containing industry standards and procedures safety
International Civil Aviation Organization	*ICAO*	Annexes Safety Management Manual (SMM)	Annex 14 - Aerodrome operation and Annex 13 - Investigation
National Air Transport Association	*NATA*	Safety 1st and Fueling	Training programs material and best management practices to enhance safety
Occupational Safety and Health Administration Voluntary Protection Program	*OSHA* *VPP*	Safety management Program	Performance based criteria for managed safety and health system
U.S. National Safety Council	*NSC*	Aviation Ground Operations Safety Handbook	The handbook set with four guidelines for safety of ground operation

III. Case Study

In the following chapter, the research about ground handling safety and human factors will be presented. It was performed under the authority of the ECAST (European Commercial Aviation Safety Team) by the Air Transport Safety Institute of the NLR (National Aerospace Laboratory) in cooperation with the Civil Aviation Authority of the Netherlands. The main objective of this research is to investigate the causal factors which lead to human errors in ground handling operation at Netherlands. Human errors create unsafe environment on the apron and even various accidents or incidents which can result in additional costs for an airline or other parties involved. The result provides current situation overlook of apron safety at main Netherlands airports and basic recommendations to the participating parties.

Data for this study were provided by seven ground service operators within the Netherlands. Required information was gathered by the questionnaire that was distributed to two main groups: Management and Operational personnel. Average response rate was 33%. The meaning of this study was based on the opinion of ECAST GSWG (Ground safety working groups) that human factors aspects are not enough introduced in the ground handling operation. According to them, this can prevent a lot of incidents/accidents and improve the safety of ramp personnel and lower the damages costs. Therefore, the first part of this chapter aims to access the companies´ safety culture and the second part is focused on human factors in ground handling operation.

With regard to human factors, attention is paid to:

- Emphasize awareness of the potential risk of human factors like time pressure, stress, fatigue, communication and training on how to manage these factors;
- Standardization of phraseology on the ramp.

With regard to safety culture, points of attention are:

- Propagation of the safety policy and principles by management to operational personnel;
- Substantiate and elaborate the principles of a just culture;
- Communication of safety related issues by developing and maintaining a safety reporting system;
- The "visibility" of management to operational personnel

In order to acquire the necessary information, the questionnaire was applied to ground handling personnel and providers. This information, which originated directly from companies, proved themselves extremely valuable. Therefore, final cooperation was set between following organizations:

- Amsterdam Schiphol Airport: Aviapartner
- Amsterdam Schiphol Airport: KLM Ground Services Department
- Amsterdam Schiphol Airport: Menzies Aviation
- Amsterdam Schiphol Airport: Servisar
- Rotterdam The Hague Airport: Aviapartner
- Maastricht Aachen Airport: Maastricht Handling services
- Eindhoven Airport: Viggo

The used questionnaire form consists of two main sections. The first one aims to examine the safety culture of named GSP (ground safety partners), using the Culture Inquiry Tool. The second one aims to examine human factors that occur in ground handling processes. In this second section REDA (Ramp Error Decision Aid) results were used.

Each participant had to give a rating from one to five for each statement presented in the questionnaire. If the answer was not applicable, no rating is added. The rating of each indicator was estimated as an average of the statements and the overall rating of all participants was calculated as an average of all ratings without weighing factors.

In the seven participating GSP, 1174 questionnaires were sent, divided into 172 for management and 1102 for operational personnel. The average response rate was 57% for management and 19% for operational personnel. Figure 1 below provides the average levels of safety cultures of participating GSP. The rating ranges from 3.4 to 3.8 (compared in Hudson´s scale of 1-5). Since these numbers provide just a rough indication, a more detailed research, later in this chapter, was conducted on the safety culture of each GSP.

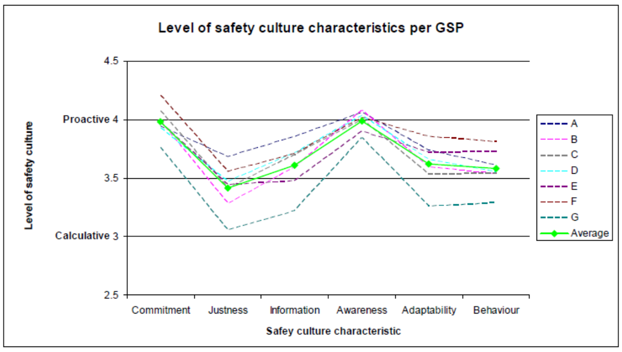

Figure 1 *– Level of safety culture characteristics per GSP [2]*

In all cases, a high rating was measured for two characteristics, Commitment and Awareness. These are very positive traits of the GSP and it should be improved further. Commitment towards safety is base assumption in order to maintain safety culture of an organization. Extensive risks awareness makes sure that personnel is well acknowledged and work as safe as possible.

However, the commitment and awareness are on a very good level, the safety culture characteristic Justness shows the lowest rating of all. As it was explained earlier, justness reflects the level to which is personnel´ safe behavior encouraged or rewarded and unsafe behavior is discouraged. This should be the point where the organizational management steps in. It is important to preserve justness in order to maintain safety culture. The ratio from returned questionnaires even justifies the fact that justness is not on the required level.

Another thing which is particularly disturbing is that one of the GSP provides lower rating on all characteristics.

When outputs of management and GSP personnel are compared together, management typically provides a higher rating than GSP personnel on the safety culture indicators. This can be caused by a very optimistic view of management to their own activities or even to whole organization.

INCIDENT ANALYSIS

Figure 2 shows the views of management and operational personnel on the occurrence of incidents. The incidents are displayed from high to low frequency.

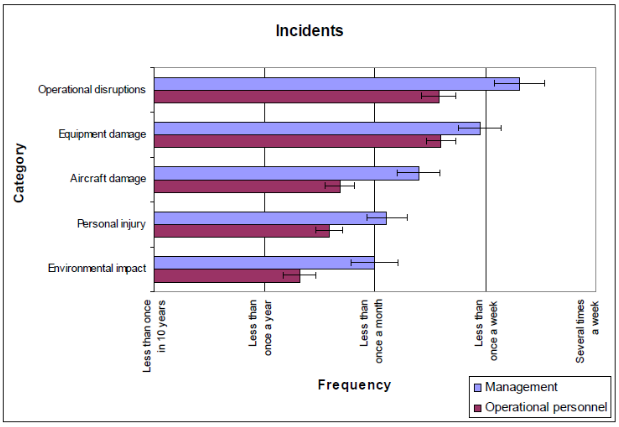

Figure 2 – Frequenciesof incidents perceived by management and operational personnel[2]

Quotable are significant differences that are between the opinions of management and operational personnel. It is probably caused by fact that management has wider view on operation and therefore can better estimate the incidents occurrence.

DIRECT CAUSES

During investigation of incidents causes it is important to identify the type, time of appearance, frequency and human factors of these incidents. Figure 3 below shows the overview of management and operational personnel observations with regard to the direct causes of accidents, incidents and human errors. These direct causes are ordered according to the frequency they occurred.

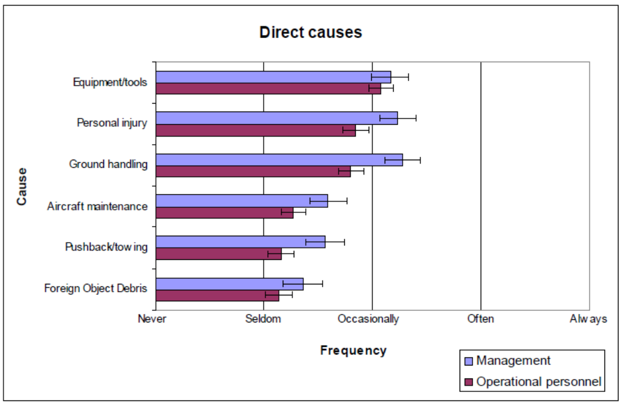

Figure 3 – Directcauses of incidents, accidents and human errors[2]

As it can be seen in Figure 3 above, it is stated by operational personnel that most of the accidents, incidents or human errors occurred during ground handling were caused by improper or insufficiently maintained equipment.

However, management attribute these incidents, accidents and human errors to ground handling operation, it is alarming that most of ground handling personnel see problem in equipment itself.

CONTRIBUTING FACTORS

In this section, the factors contributing to accidents, incidents and various human errors on apron are examined. Perceived frequencies from both management and operational personnel are included in graphs. Figure 4 displays the perceived frequency of factors that lead to an incidents.

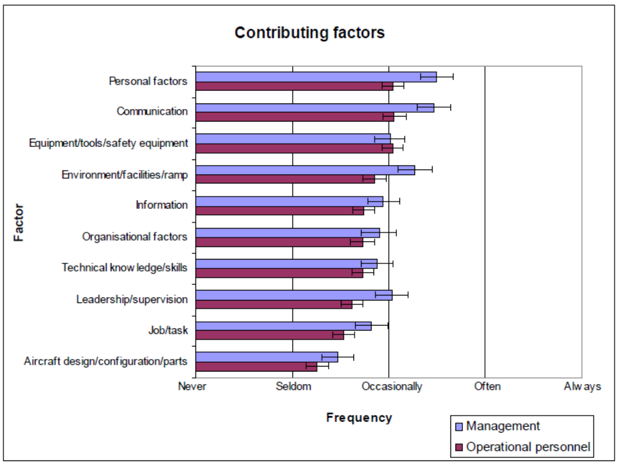

Figure 4 - Contributing factors[2]

Time pressure was stated as the most frequent contributing factor in ground handling by both management and operational personnel in Netherlands. Also stress and fatigue, which are closely connected to time pressure, were ranked very highly in the analysis. Another important information, which we perceived during interview with operational personnel, is that they need to take double shifts in order to generate sufficient income. Peer pressure and motivation are also quite reasonable factors to consider further.

OTD (On time departures) are typical time pressure factor. Scheduled departures are commercially important for each airline. OTD force the ground service providers to keep deadlines due to contractual arrangements. As a result, they need to work under heavy time pressure many times, what and this can lead to human errors.

The safety culture of GSP plays an important role in the correct management of time pressure. From the safety culture assessments it was determined that within the safety culture characteristic awareness, the indicator attention for safety provided the lowest rating for all participating GSP. This related partially to whether the primary concern is to work safely or to meet the scheduled departure time.

In one of the interviews it was told that operational personnel often see safety and a fast turnaround to meet the OTD as incompatible, whereas in reality there is always a balance between safety and speed. This balance may differ for each turnaround due to the dynamic environment or different conditions, but when the right balance is found, safety is not compromised.

With regard to the contributing causes, personal factors and communication receive a relative high frequency from both management and operational personnel.

Personal factors that mostly influence safety on an apron are time pressure, stress and fatigue. These are related to the most frequent operational disruptions which is delays on arriving or departing flights. Time pressure and its influence on safety can be lowered when the main focus in changed from on time departures to on time arrivals. It is also recommended to provide awareness training to teach operational personnel how to deal with time pressure.

Communication among different departments received relative high frequency as a contributing factor. It can be caused by too complex and standardized phraseology. Again, awareness training can lower the chance of communication errors on the apron among different departments.

There are differences between the views of management and operational personnel with regard to the contributing factor equipment/tools. Management seeks the contributing factors of human errors and incidents primarily in incorrect use, or lack of use, of the ground handling equipment or personal protective equipment. Operational personnel, on the other hand, expresses the view that bad maintenance, poor reliability and poor safety of the equipment contributes to errors and incidents. This is in line with the findings in the safety culture assessments, in which operational personnel often expressed their view that maintenance of ground handling equipment is insufficient. It is important for management to be aware of the importance of this equipment to the operational personnel.

IV. Conclusion

The aviation industry can point to a number of reasons for the increase in ramp accidents and incidents, such as outsourcing staff, higher volumes of flights, increased congestion in the ramp area, larger aircraft, fewer airport operations staff, and cost-cutting measures with regard to training, equipment, and staff supervision, but the increase of 15% in accidents/incidents rate measured from 2006 to 2007 is particularly alarming and numbers of accidents/incidents are yet still growing each year.

Thus, this challenge has to be faced by all stakeholders, i.e. airports, airlines and ground handling services providers. One of the possibilities, how to approach this issue in order to investigate it, is described in this paper. Questioner is commonly used tool and its result can have significant impact when assessing how to mitigate the operational hazards.

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HUMAN FACTORS IN ACCIDENTS OF THE SMALL AIRCRAFT CATEGORY

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***Abstract** – The article focuses on the safety of civil aviation, which is in 80% of the accidents caused by Human Factor, Human Error or just Pilot Error. The main goal of this text is evaluation and assessment of the causes of aircraft accidents of general civil aviation operations of the Czech Republic. The paper analyzed accidents of aircrafts in the category with maximum take of mass to 2250 kg and ultra light aircrafts incurred in the Czech Republic from 2006 to 2012. In the conclusion were analyzed main causes of the aircraft accidents and were proposed further measures to reduced accidents caused by Human Factor..*

Key words – Aircraft, accident, human factor, occurence.

I. INTRODUCTION

The article discusses the safety of civil aviation, which is, according to statistics FAA in 80% as the main culprit of the accident or incident marked the human factor, human factors, human error or pilot error only. Problems of study and elimination of negative human impact on accident rates in aviation has become increasingly examined until 70 the last century, especially after biggest fatal accident on the island of Tenerife, in which 583 people died. It is therefore a relatively new scientific discipline primaly concerned on commercial air transport only.Unlike the technical causes of accidents and incidents are unfortunately unable to adequately eliminate the number of aviation accidents and incidents caused by just the human factor. Despite the very high aviation safety in the event of any safety extensively publicized and monitored. This has subsequently large impact, including economic losses airlines, especially on passenger confidence in air transport, which is according to statistics safest way of collective or personal travel at all.

Negative effects of human factors also cause problems in general and sports aviation. The issue of human factors in the general aviation receives only gradually and still he does not pay so much attention what it would be needed.

It is a positive fact that aviation regulations dealing with of aviation personnel also contain requirements for theoretical training pilots in the field of human performance and limitations.

II. THE REQUIREMENTS FOR KNOWLEDGE OF HUMAN PERFORMANCE AND LIMITATIONS

The JAR - FCL 1 clearly defines the areas of theoretical knowledge required the necessary pilot practice. For the aviation physiology Some of the basic concepts such as atmospheric composition, respiration and blood circulation, effects of altitude change to partial pressure physiology of sight, then hearing, motion sickness and the effect of flying on the health of the organism, and the risk of toxic substances. From the category of basic psychology regulation includes areas such as processinginformation, the central decision channel, and stress assessment and decision making.

PROGRESSION OF HUMAN FACTOR

The actual human behavior and performance are a total of about 80% cause all aviation accidents and incidents, compared to 20% of air emergency event of technical or other reasons. To reduce accidents and safety in aviation you need to just focus on the best possible understanding of issues of human performance, human limitations and human errors and theoretical knowledge was subsequently bring education on how to pilot or other training into practice.

Impulse directing air and professionals on the importance of addressing questions dealing with the decline in performance and failure pilots brought in 1975 by technical Conference of the International Air Transport Association (IATA) in Istanbul and symposium International Federation of airline pilot in 1977 in Washington.

MODEL OF THE HUMAN FACTOR

The human cell is throughout the aviation system the most flexible, most adaptable components system. But it is also vulnerable to various disturbances and other influences affecting its performance. Also, the reliability and quality of work are perhaps Human factors weakest in civil aviation as a whole.

Use of the term pilot error does not significantly help for the prevention of accidents, on the other hand has a rather negative. Pilot error because it refers only to that place in the system, where you went wrong. It is therefore not clear why there was this error never happened. it is In principle, the main aim of the interview itself causes accidents and subsequent prevention due to known causes.

For understanding the needs of people with different backgrounds, different education for different positions was necessary to create a completely unified ideological foundation and terminology dealing with Human factor. This became the ideological basis of the conceptual model SHELL.

Errors generation during flight may arise from different causes. The most errors can be analyzed and subsequently eliminated by the SHELL model:

S - Software - incorrect application of standard procedures to the situation, use of inappropriate procedures due to the problem. Failure to comply with the prescribed tasks in different phases of flight.

H - Hardware - disorders aircraft avionics systems, management controls, power unit.

E - Enviroment - above all changes in meteorological conditions.

L - Liveware - failures in communication, both manned with ATC or with ground personnel.

L - LiveWare - pilot - changes in physical or mental status, in attention, lack of discipline etc.

The model shows a good connection parts of software, hardware, enviroment and Liveware to central element of the system, in this case the pilot.

The requirement of flight safety has absolute priority in aviation and it is in this area concept of human factors proved to be an effective way of objective knowledge and support ways to bring the highest level. A key finding was leaving the view that the Human factor is identical with a particular individual (pilot) who failed or has committed errors. This attitude led and sometimes still leads to the conclusion that failure is always a matter only individuals and thus not an individual in an imperfect system. Which in many cases is not completely true.

Very detailed research into the sources of errors and mistakes failures staff Aviation is dedicated to prof. James Reason. By adjusting the current model of the Human factor - model SHELL, reached a more realistic and actually closer four level user model causes failure of man. He called it the Swiss Cheese Model of Accident Causation.

HUMAN PERFORMANCE AND LIMITATIONS

If you can not under any circumstances unfailing level of human performance is Aviation completes the overall concept and training in the field of human factors. Need Human Factor research in the aviation industry is based on its significant impact on the total two large areas, which together inseparably interconnected manner and sometimes In its influence overlap, one of which can easily affect the other. These area is both the efficiency of the system (including safety and performance) and health status of members of Aircrew.

Health is essential for human biological need that is necessary to for his personal well-being and successful management of all necessary activities. All health disorders, diseases and their consequences can cause serious complications, either the lack of pre-flight preparation or during the flight itself, when such a failure may be one of the main factors behind the occurrence of an extraordinary event.

The concept of health is closely related to the physical condition, which can be defined as a state organism, which allows a person to give the desired performance, without at the same time Crossing the border physiological adaptation to workload.

The ability to critically assess your current fitness is one of the key pillars safety, safe and above all responsible behavior. At least the basic own self would be able to each. For itself. However, if this assumption fails and it is clear that a person is something wrong, it should have worked good team safety climate.

ERRORS AND HUMAN RELIABILITY

Reliability of the individual is defined as its ability to accomplish the desired task, exactly perform necessary tasks and consequently come to an end. In real operation is one constantly required to perform a large number of tasks of various degrees of difficulty and complexity, with the added then, open space just for errors. This error can be defined as any action resulting in other than its original intent required.

The errors occur in the event that mastering the rules and procedures used inappropriately, or at the wrong time. Unlike oversights, omissions and errors, which include into common categories of human error, for offenses not considered errors. They are manifestation of intentional disregard of rules and regulations. For reliable performance air profession and to avoid mistakes is crucial compliance standard operating procedures.

SPRM - Single Pilot Resource Management, is the name for a complex methodology of improving the performance of the pilot using all participants in traffic. This system is applicable to all forms of training pilots and focuses mainly on the behavior and attitudes of pilots and their impact on flight safety. It is opportunity for individuals to explore themselves and their behavior and adopt individual decisions as improve safety in aviation.

III. AIRCRAFT ACCIDENTS

For the analysis of Aircraft accidents were chosen category airplanes with MTOM to 2250 kg and ultralight aircraft on the ground that a similar category aircraft nowadays with similar features but with different overall philosophy of operation.In civil aviation Czech Republic and in all possible categories of aircraft occurs year many accidents and incidents. Overall, the reported each year around 700 occurences.

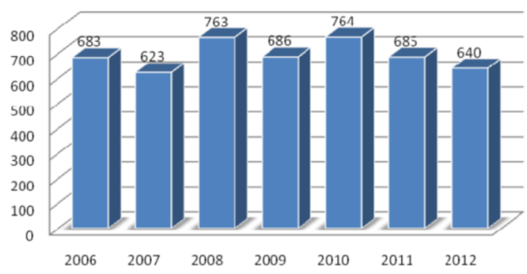
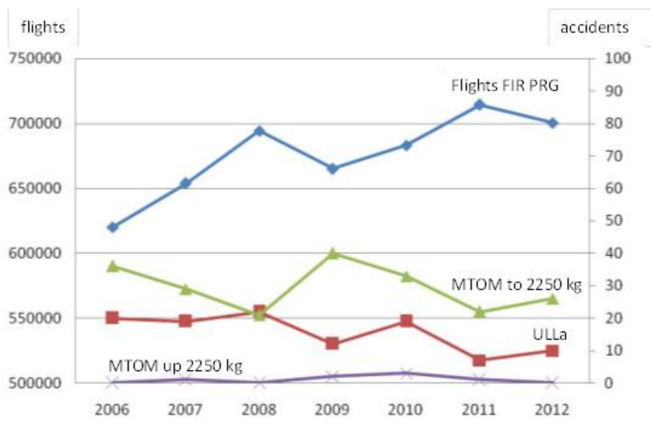


Figure 1 *– Number of reported occurrences in civil aviation of the Czech republic*

The largest proportion of all reported events are categories of aircraft with MTOM up to 2250 kg. But it is not only the events of airplanes, this also includes such helicopters or gliders. This category aircraft with SLZ - also known by the acronym ULL or microlights, almost two thirds of all reported incidents in civil aviation operation.

The next graph shows the difference in the number of Aircraft accidents with MTOM up to 2250 kg aircraft MTOM over 2250 and SLZ, depending on the traffic in the airspace space FIR Praha (only flights with the filed flight plan) and its progression in recent years.



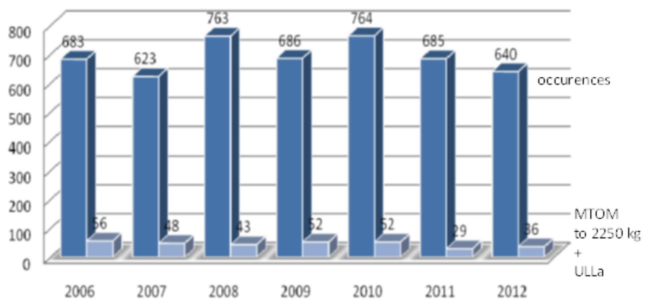


***Figure 3** – Number of Aircraft accidents ULLa and MTOM to 2250kg categories*

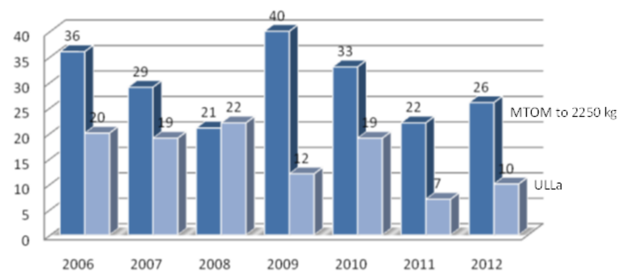


***Figure 4** – Number of all occurences and Aircraft accidents ULLa and MTOM to 2250kg categories*

THE INFLUENCE OF HUMAN FACTORS ON SMALL AIRCRAFT ACCIDENT

The theory has been repeatedly mentioned the fact that the human factor is involved up to 80% of the accidents. This number gives the example of their statistics FAA. Verification of this claim was one of the main objectives of this paper and its analysis of the impact of Human factor on small aircraft accidents.

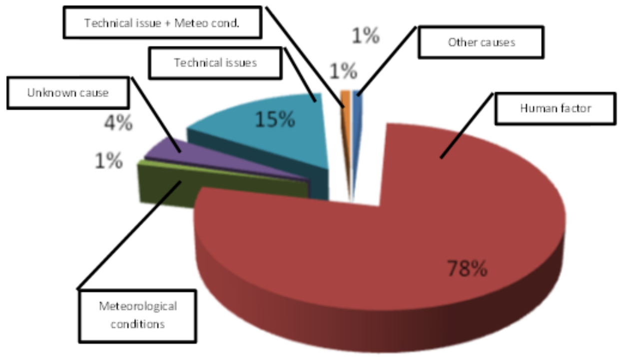


***Figure 5** – Aircraft accidents causes*

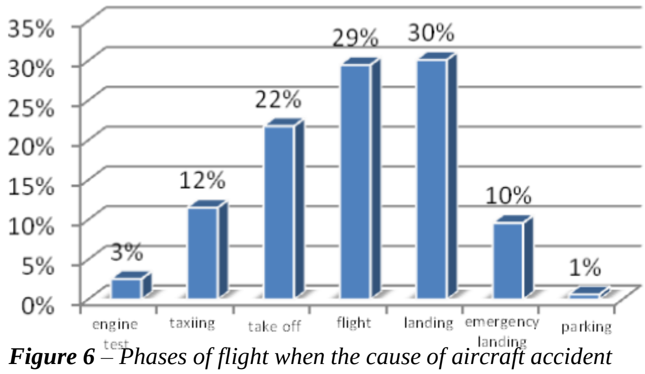


***Figure 6** – Phases of flight when the cause of aircraft accident caused by the human factor*

The result of the analysis phase of Aircraft accident caused by the human factor is graph above. It is therefore clear that the most critical phases in the general Aviation is taking off and landing as in commercial air transport, but also years landing and after several percent also take off.

In analyzing the causes of accidents were defined specifically for aircraft with up to 2250 kg MTOM and SLZ (sport aviation facility). Both of these categories is of similar representation causes of human factor influence just human error when the aircraft is 76% and SLZ 79%. The differences are, however, a second preview evident in parts where the human factor failed. For example, the fault for failure to comply with prescribed practice has a surprisingly high proportion of the category of professional pilots, on the other hand is represented almost the opposite in cases of indiscipline flight, where, however, such a difference can be expected.

Results similarity technical reasons are quite surprising and particularly on the grounds that the aircraft with MTOM to 2250 kg there are significantly more stringent conditions bothin terms of production aircraft, and in terms of operation and maintenance.

Mistakes to avoid the accident in fact even experienced pilots, but the original hypothesis of the pilots with a certificate entitling the piloting of aircraft flight commit indiscipline to SLZ, causing accidents in this category has not been confirmed.

IV. Conclusion

The analysis showed that the man, a human factor involved for all Aircraft accidents generally from 78%. This confirmed the hypothesis FAA long-term stabilization causes of accidents due to human error on the values of around 80%. The remaining share is from the top of the technical causes that contribute to the occurrence of accidents of 15%. The rest of the causes is negligible .

When applying the results of the analysis of accidents that category of aircraft using the SHELL model, as the riskiest showed interactions between cells L – H showing the pilot and the aircraft itself, thus failing to piloting techniques primarily at the stage of take-off, flight and landing. Furthermore, the critical interaction between cells L - S, by failure to comply with required actions in a limited number on the interface L - E, which reflected the lack of pre-and underestimation of the potential of weather.

It is also confirmed by the fact that the central point of the system, in this case, the pilot is weakest and riskiest article at all. Generating there are a number of both unintentional errors, mistakes and carelessness, but also a number of violations, like flight indiscipline.

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USING CATALYST FOR REDUCING EMISSION IN AVIATION

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Abstract*– as the aircraft contribute in producing gases that cause pollution and global warming, it become necessary to find solution to reduce aircraft emissions. In this paper I wrote about aviation fuel, emission produced by aircraft and how it can be reduced by changing some of motors design or using catalytic converter (two or three ways).*

Key words– pollution, emission, aircraft, fuel, catalyst.

INTRODUCTION

The increase in aircraft pollution is largely due to the rapid growth in air traffic which has been expanding at nearly two and half times average economic growth rates since 1960. It is expected that, the number of people flying will virtually be doubled over the next 15 years. This means increasing airport capacity, more flights, more pollution and increasingly crowded airspace.

Emissions from aircraft flying at cruising altitudes (8 to 13 km) affect atmospheric composition in a height region where there might be significant climate impact through changes in the chemical and physical processes that have climate change consequences.

Future emissions from aircraft are expected to increase much more rapidly than emissions in general, with global aviation annual growth currently estimated between 4 to 5%.

Aviation emissions are relatively small compared to emissions from other transport (automobile). These emissions are gradually reduced, because of changes in fuel composition, using alternative fuel, engines modification, and emission controls on motors during technical controls.

In the other hand, the aviation fuel is always the same. It contains lead which has harmful effect on environmental, and incompatible with catalytic converters.

The aimof this presentpaper isto focus onways to reduceemissions of smallandultra-lightaircraft.

AVIATION FUEL

Aviation fuels are classified into two groups, aviation gasoline (Avgas) and aviation turbine fuels (Jet fuel). Avgas is an aviation gasoline that is suitable for use in aircraft that have piston engines. Jet fuel is an aviation turbine fuel suitable for use in aircraft with turbine engines.

AVGAS (AVIATION GASOLINE)

Avgas is used in small piston engine powered aircraft, within the General Aviation community. Predominately activities such as private pilots, flight training, flying clubs and crop spraying. Piston engines operate using the same basic principles as spark ignition engines of cars, but they have a much higher performance requirement.

In today's General Aviation community there are only two main Avgas grades (100 and 100LL low lead) – a rationalization that has enabled fuel companies to continue supplying a market that would otherwise have become uneconomic. Worldwide, total Avgas volumes are low, since Avgas-fuelled aircraft, although they outnumber jet-fuelled aircraft, are generally much smaller.

AVGAS GRADE

Avgas 100 is standard high octane fuel (100-130) for aviation piston engines. It has a high lead content (2.11 g/kg) and is dyed green.

Avgas 100LL is low lead version of Avgas 100 (0.75 g/kg). Its octane number is 100 and it is dyed blue.

Avgas 82UL this is a relatively new grade aimed at the low compression ratio engines which don't need the high octane of Avgas 100 and could be designed to run on unleaded fuel. Avgas 82UL is dyed purple, its octane number is 85 and lead content is 0,41g/kg.

BA 95 natural is unleaded automotive gasoline.

The following table shows the energy content of avgas and other fuel.

Table 1*- energy content of fuel*

fuel	Energy content [Btu/gallon]	Energy content [MJ/dm3]
Biodiesel	120000	33,42
Gasoline	117249	32,66
Avgas	112500	31.33
LPG	84000	23.39
Ethanol	80000	22.28
CNG (3000 psi)	38000	10.58

DESCRIPTION EMISSION

Main aircraft emissions are:

Carbon dioxide (CO_2): It is production of complete oxidation, its presence in exhaust gases is an index of complete combustion. It is colorless gas,has a slightly irritating odor, very stable and little active.

Carbon monoxide (CO): It is an index of insufficient amount of oxygen in exhaust gases, that maybe in one or more cylinder or in other zone in the motor. It contributes in formation of photochemical smog.

Nitrous oxide (N_2O) and nitrogen oxides (NO_x): Nitrogen oxides are produced at high temperatures and pressures, and its existence depends on oxygen concentration. Nitric oxide (which is toxic gas) represented the largest proportion 95%. The most significant effect of nitrogen oxides (NO_x)is on ozone layer whereas it destroys the ozone molecules according to the next equations.

$NO + O3 \rightarrow NO2 + O2$

$NO2 + O \rightarrow NO + O2$

So that more of harmful ultraviolet radiation will reach the earth

Methane (CH_4).

Sulfur dioxide (SO_2): Sulfur dioxides along with nitrogen oxides combine with water in the atmosphere to form acidifying compounds. These are later deposited on the earth's surface and can cause acidification of soil and lakes.

Volatile Organic Compounds VOC: It is a mix of unburned fuel, motor oil, and incomplete combustion and pyrolysis.

Soot: Is impure carbon particle, resulting from the combustion of evaporated drops of fuel at high temperatures and very low value of excess air. It is highly efficient at absorbing solar radiation that is the reason of current warming effect

Emission amount depends on type of fuel, aircraft and motor, motor load and flight level.

INFLUENCE OF MOTOR DESIGN PARAMETERS ON PRODUCING EMISSIONS

EXHAUST GAS RECIRCULATION

The role of EGR is to act as inert diluents and heat sink that reduces the oxygen concentration during combustion and lowers the combustion temperatures. The flame temperatures are reduced as a result of EGR. The NOx formation being an exponential function of temperature, even a small reduction in flame temperature has a large effect on NOx formation.

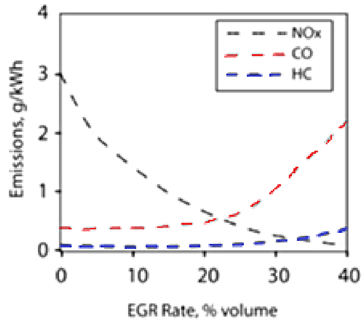

Figure1*– Typical effect of EGR on NOx, HC and fuel economy for a turbocharged, intercooled passenger car DI diesel engine*

At around 10% EGR, 50% reduction in NOx is obtained with little change in CO and HC. As the EGR rate is increased beyond 15 %, NOx decreases further, but CO, smoke and HC are increased. The excess air declines with increase in EGR causing sharp increase in smoke and loss in fuel economy.

EFFECT OF COMPRESSION RATIO

Using of higher compression ratio results in a shorter ignition delay period. A shorter delay would result in less 'overmixing' of fuel and air and hence, lower HC emissions. Further, the higher combustion temperatures obtained at higher compression ratios tend to increase oxidation of the unburned HC. It would also increase soot formation, while on the other hand it increases soot oxidation.

Using of a low compression ratio results in too long delay during engine warm up under cold conditions and it causes high emissions of unburned fuel which due to its appearance is called 'white smoke'.

For obtaining low particulate and NOx emissions simultaneously, an optimum compression ratio is to be used.

FUEL INJECTION TIMING AND INJECTION PRESSURE

With retarded injection timing, as expected the NOx emissions decrease sharply. On the other hand an increase in smoke results with retarded injection timing, if the injection timing is retarded too much. HC emissions in naturally aspirated engines also may increase sharply. An increase in injection pressure results in higher NOx and HC, but yields lower smoke and PM emissions.

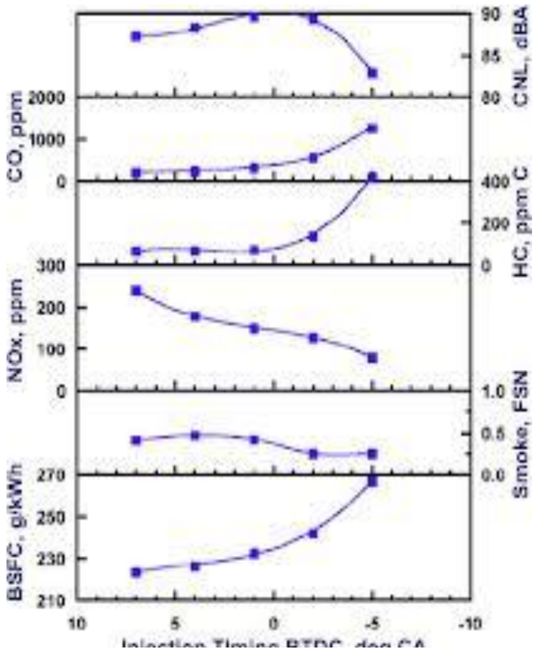

Figure 2*– Influence of fuel injection timing on emission*

ENGINE LOAD AND SPEED

With increase in engine load (increase in fuel-air ratio), NOX and soot emissions increase. However, HC emission reduces with increase in engine load as higher gas temperature lead to an increase in the oxidation rates. The combustion temperatures increase with increase in engine load and oxidation environment for CO is more favorable, CO emissions decrease until excess air reduces to about 30 percent.

USING CATALYST FOR REDUCING EMISSION

CATALYST CONSTRUCTION

Catalyst is thin layers of precious metals ex. (palladium, platinum and rhodium) applied on the grid of catalyst, which induce and speed the reaction of products imperfect combustion and their decomposition to less dangerous products.

Catalysts are produced in many technical designs, which are different in durability endurance, cleaning quality and flow. In automotive industry, it is used catalyst with steel carrier, which is suitable in intensive conditions, because of their low flow resistance and high mechanical and thermal resistance. The thin wavy film of high-alloy steel is rolled into the shape of the letter "S", which significantly reduces internal stresses at high temperature changes. Layers of film are soldered to each other and to the outer cylinder casing. "S" shape with two centers also prevents degradation carrier's telescopic effect, which sometimes happens with catalysts simpler structure. On metal wall rack is coated lining of aluminum oxide (Al2O3). It is a highly porous material to which it is applied only own catalytic layer of precious metals (platinum, rhodium, palladium). This makes the reaction area of the catalyst larger.

Optimum working temperature inside catalyst is 250-800 ˚C. In the period before the temperature reaches 250 ˚C the catalyst is ineffective. That is in the status of cold start shortly 30-60 second after start. At lower temperatures (to 600˚C, it is recognized clogging the active area of catalysts, with slow thermal aging. At temperature range (600-800 ˚C) the clogging catalyst reduces, but the thermal aging increases.

TWO-WAY AND THREE-WAY CATALYST

Two-way catalyst (oxidation) catalysts are able to reduce emissions HC and CO, three- way catalysts (oxidation-reduction) reduce emissions HC, CO and NOx. Since the oxidation catalysts are not used in modern petrol engines.

In order that the three-way catalyst works properly, it must be enough amount of oxygen in emission. These catalysts work at combustion of exactly stoichiometric mixture fuel- air, (1kg fuel+ 14.8 kg air) when excess air coefficient =1.

In order to achieve stoichiometric mixture fuel-air, it is used so-called lambda sensor, which measure oxygen amount in the emission. According to this amount, the amount of fuel into the cylinders is regulated. Three-way catalyst is ineffective without lambda sensor, because the default mixture richness is not corresponding to the requirement of current combustion conditions. The catalyst body should also be enough warmed to fill its function.

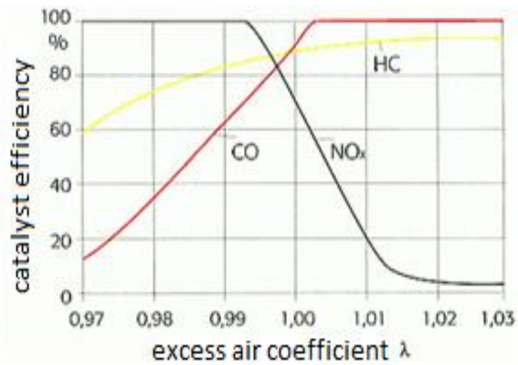

Figure 12*– Influence of excess air coefficient on catalyst efficiency*

INFLUENCE OF CATALYST ON AIRCRAFT EMISSIONS

Using three-way catalyst in petrol engine reduces CO emission 15 ×, HC and NOx to 10×. CO and HC are oxidized to carbon dioxide (CO2), which is one of greenhouse gases that cause global warming. Petrol engine with catalyst produces three of six greenhouse gases listed in Kyoto protocol, which are (CO2, CH4 and N2O).

Although methane content is reduced when using catalyst, but in the same time the content of carbon dioxide increases with increasing conversion efficiency of CO, HC and CH4 to CO2. In term of greenhouse gas emission, that will be positive, because methane contributes in global warming 21× more than carbon dioxide. Moreover, the modern three-way catalysts cause greater amount of N2O, whose greenhouse effect is 310 times greater than CO2. The greatest amount of N2O is created when using Rh, Pt, Pd (three-way catalyst). Whereas using Rh Pt (two-way catalyst) produces the smallest of N2O.However, with catalyst aging this amount increases, probably with the thermal connection. N2O produced in presence of Pd catalyst persists even at high temperatures above 500 ° C.

Using catalytic converter in engines working on leaded fuel (avgas 100, 100LL) is not possible, because the lead deactivate the main catalyst elements (platinum). Therefore, catalyst can be used in aircraft engines that work or may work on unleaded avgas (UL91) or automotive unleaded fuel (Mogas).

To the motors working on unleaded Mogas belongs Rotax 912 IS, 912 S/ ULS. All engines already approved to use unleaded Mogas RON 95 (MON 85) in accordance with Standard EN228:2008 are deemed as suitable for operation with UL 91.[2] To the motors that can work on motor gasoline belong Lycoming O-290/ O-320 and others. [2] Aircrafts permitting to use motor gasoline are listed by UK Civil Aviation Authority CAA. [2]

CONCLUSION

Aircrafts supplied with catalytic converter produce less greenhouse emission HC and NOx, in case of achieving optimum excess air coefficient and working temperature in catalyst. However, it is important to note, that using catalyst must be combined with using unleaded fuel. Therefore, we recommend using unleaded automotive fuel. Application of catalyst for engines type Textron, -Lycoming, Rotax and Sabaru with power 70-140 kW requires processing of design weight analysis.

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UTILIZATION OF THE PCAS (PORTABLE COLLISION AVOIDANCE SYSTEM) IN THE SLOVAK AIRSPACE

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Abstract *– This paper deals with the issue of Airborne Collision Avoidance Systems (ACAS). Particularly it focuses on the relatively inexpensive instrument used primarily by a general aviation PCAS (Portable Collision Avoidance System). Paper discusses its performance in the specific region of Slovak Republic. Research performed at the University of Žilina pointsat its advantages and shortcomings in real traffic usage.*

Key words – Traffic Advisory, Airborne Collision, Flight safety, PCAS

I. INTRODUCTION

Research and development of this system was led by a company Zaon Flight Systems whose primary goal was to design affordably priced system that would provide pilots complex information about the surrounding traffic. This system has its roots in the year 1999 and nowadays its fourth generation is available. System PCAS is primarily aimed at small and medium sized aircraft of general aviation and at ultralight aircraft.

In contrast to TCAS system the PCAS is a passive system that monitors the surroundings traffic by utilizing a special built-in antenna up to an 11km distance. This passive system works on a principle of monitoring the surrounding aircraft that are equipped with a functioning transponder or a TCAS system. Zaon XRX is able to monitor up to ten aircraft and for three aircraft that are potentially the most dangerous for traffic the system is capable to indicate 3D parameters. Display indicates their relative height, relative distance and their tendency in the vertical height towards the specified aircraft. Zaon XRX with regard to the anticipated traffic enables the pilot to select the indication extent of traffic from 1 up to 6NM (from 1.8 up to 11km) with the following precision:

0.4 – 1.9 NM ± 0.1 NM

2.0 – 2.9 NM ± 0.2 NM

3.0 – 6.0 NM ± 1.0 NM

Built-in pressure sensor for determination of the relative height allows the pilot to select the range of monitored surrounding traffic in three altitudinal planes namely ± 500ft, ±1500ft and 2500ft. Itis possible to use this instrument in the pressurized aircraft as well, however in such conditions the height used for calculation and indication will be used from the data provided by the transponder of the particular aircraft.

It is possible to interconnect the system with pilot's headphones or with aircraft's built-in speaker in the cockpit to provide audible information about the potential threat. It is also possible to adjust the indication of current height – flight level, flight course and default transponder code of the particular aircraft. Zaon XRX system can transfer all the information through RS-232 data port directly on the display of the GPS devices Garmin 396,496/495,696/695, 796/795, AERO 500/550, system DynomSkyView or into the iPad system Flight Guide iEFB designed for planning of VFR and IFR flights.

Figure 1.*-Apple iPad device with software for flight planning*

Zaon XRX device is a standalone, portable system that does not need to be interconnected with the aircraft permanently and it is usable both in the metal and composite aircraft.

Figure 2.*-PCAS-XRX system*

2012 and the second one is mobile and can be used in any aircraft should it be needed. Until this day there were carried out 156 flights with this system with an aggregate flight time of 226 hours and 45 minutes.

Because itis a passive system and with respect to the relatively mountainous terrain of Slovak Republic the rate of utilization is questionable. For its correct functioning it is necessary that the aircraft in its vicinity are in the range of the secondary radar or in the range of aircraft with active anti-collision system TCAS. Multiple coverage of Slovak Republic by a signal of secondary radar in the flight level FL100 is guaranteed by an aeronautical service provider (Figure 4). From a given figure it is clear that for a FL100 and above the usage of such a system is without limitations.

From practical experience obtained during testing itis clear that the occurrence of targets under the height of 4000ft. has a very unfavourable effect on surveillance capabilities of PCAS system. On some specific locations in Slovakia there are even some flight levels above this boundary that don’t have secondary radar coverage.

Figure 3.*-System PCAS on the dashboard of Z-43 Aircraft*

II. EXAMINATION OF THE UTILIZATION OF THE PCAS SYSTEM

System is currently being tested at the University of Žilina in Žilina in order to evaluate its practical usability in the conditions of Slovak Republic. Specifically two units of PCAS XRX are employed. One is firmly built-in in the Zlin Z-43 aircraft with a registration mark OM-LOW since the January

Mapping of the accurate Slovak territory coverage for individual flight levels would be considerably difficult and financially demanding. That’s why we have evaluated the PCAS system using a subjective assessment of the PCAS performance during each flight. Pilots who flewwith a PCAS system equipped aircraft were asked tofill in the questionnaireconcerningthe evaluationof the PCAS performance.

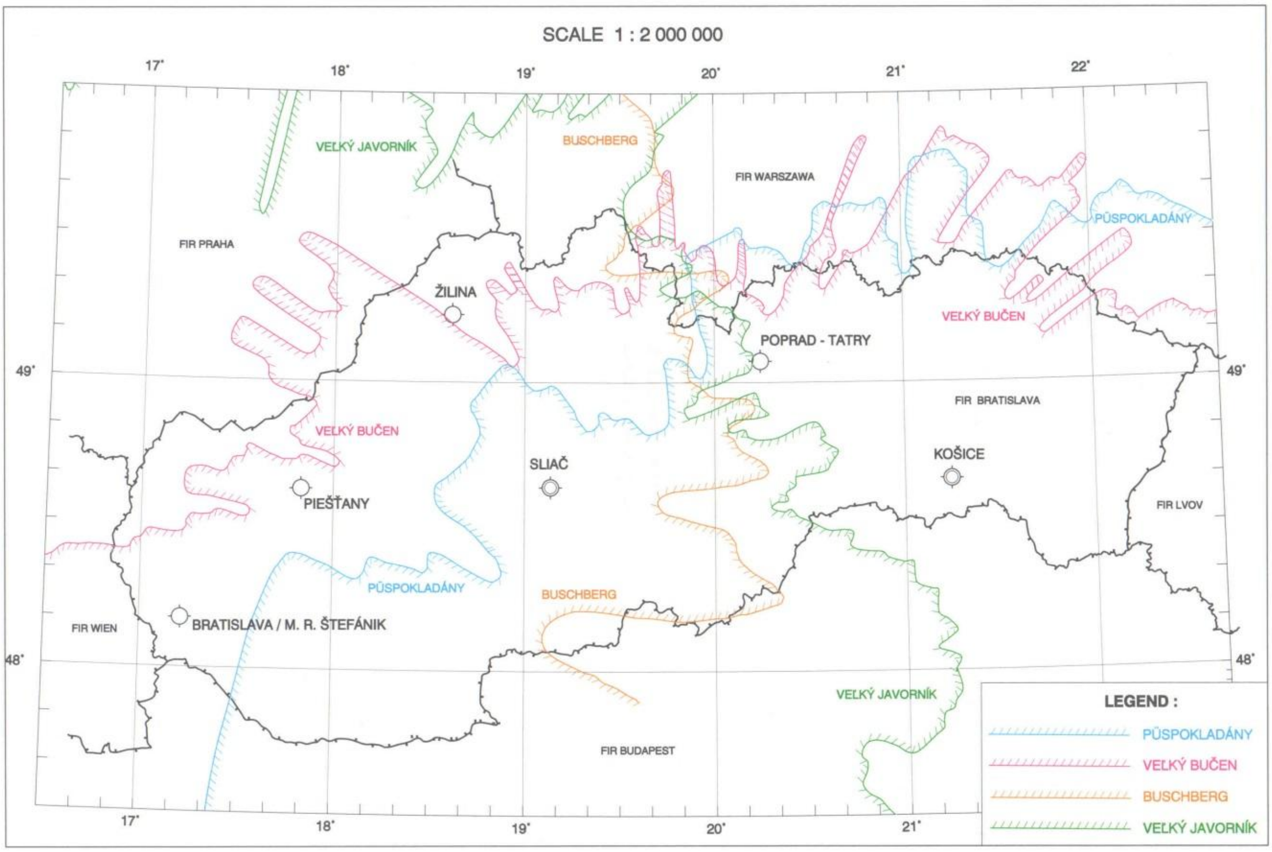

Figure 4.*-Secondary radar signal coverage of Slovak Republic for flight level FL100*

After statistical processing of all 156 flights there was not a single negative rating that would be in conflict with the anticipated performance of PCAS system during the flight outside the controlled area of Žilina airport when dealing with navigation flights carried out in higher altitudes. From all the 156 flights the performance of PCAS was assessed as insufficient in 34 cases. These cases have occurred during the flight on the aerodrome traffic circuit of Žilina airport – LZZI where the set circuit altitude is 2150ft. In three additional cases during flights in the controlled area of Žilina airport in flight altitude of 3000ft to 5000ft the system has been negatively evaluated. In these cases the system did not provide any information about the surrounding traffic even though the pilots had a visual contact with the target.

III. Conclusion

PCAS system is a contribution to a safety in air transport; however it is necessary for pilots to have clear information about its capabilities and shortcomings. This device has to be perceived as an auxiliary instrument for increasing the safety not as a key instrument. Pilots are identifying with such a statement in practice with a lot of difficulties as they are generally accustomed to a very high rate of instruments reliability aboard the aircraft. On that account some of them refuse to utilize PCAS system whose reliability of presenting adequate information is not 100 per cent.

Reliability of the system is directly proportional to the coverage of particular airspace with a secondary radar signal. Considering the mountainous character of Slovak Republic this coverage is in result irregular and for lower altitudes insufficient. In countries with a more flat relief the reliability of the PCAS system will be higher.

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THE POSSIBILITY OF EVALUATING THE LEVEL OF APPROACH SAFETY GIVEN BY THE REGULATIONS

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Abstract – This article deals with the attempt to determine the level of safety set out in regulations to allow the transition from formal compliance based oversight to oversight only the performance-oriented nature of legislation. The basis is the essence of aviation regulations that ensure the order and safety of air transport. The level of safety can also be ensured by changing the parameters and characteristics of requirements, which, however, will not conform to the formal rules.

Keywords – Safety, Safety of the approach, Regulations, CBO, PBO, ALARP

INTRODUCTION

At present, when somebody want officially implement anything in aviation it is necessary to get certification. It is issued by the competent authority, in Czech Republic it is the Civil Aviation Authority. The word certification basically means formally comply with the regulations.

This approach is referred to as CBO (Compliance Based Oversight) and is just the formal compliance of regulations. But CBO in some cases do not reflect the state of the art mechanics, or technology, and thus the compliance may be difficult or even impossible to perform. An important element is also the different speed of technological development and changes in regulations, which in Europe is still slowed down by a large number of Member States of the European Aviation Safety Agency.

Because of these reasons, efforts were made to change the nature of supervisory authorities that is called PBO (Performance Based Oversight), which will oversight not only the implementation of legislation, but also their performance.

SAFETY

Under the word safety is hiding one important feature of the system, which is perceived as the desired outcome of the procedure aimed to maintain the safety risks under control of the organization.

THE LEVEL OF SAFETY GIVEN BY THE REGULATIONS

The basic point that all organizations must fulfil in aviation is a set of regulations ranging from ICAO Annexes to CAA directives. Respecting all of these rules ensures trouble-free operation for aviation organizations. From this could be derived that, outside e.g. quality, the rules provide some level of safety.

HOW HIGH IS IT?

Determining the level of aviation safety is very complex issue, but as the current value is given $1*10^{-7}$. So, it means one serious accident to ten million flights. There is, however, the discrepancy regarding terminology, where collide two terms - accident and serious accident and under the phrase serious accident it is considered accident with death or destruction of an aircraft.

The events affecting the aviation safety are officially classified in three levels, namely: accident, serious incident and incident. Therefore to determine the current level of safety it is necessary to include in the calculation all these events. Such a calculation will be excessively complicated and informative value of the result would not be sufficient in relation to the efforts made.

Because of this, Safety management system uses the value called ALARP to determine the level of safety, where ALARP stands for As Low As Reasonably Practicable.

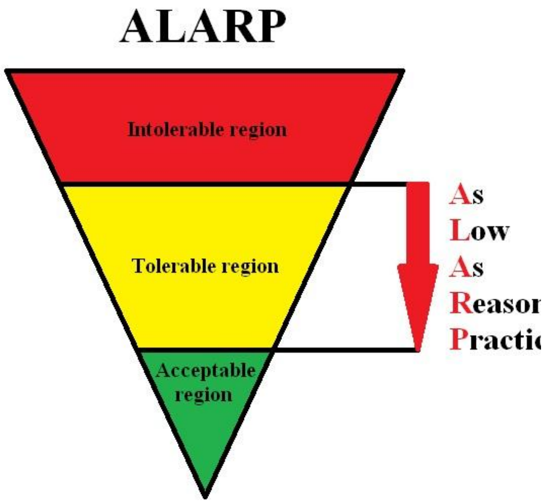

Figure 1 – ALARP

The figure shows that safety risks are divided into three categories, intolerable, tolerable and acceptable. If the risk cannot be tolerated then the operation must be cancelled. When located in tolerable region, it is possible to tolerate the safety risk, but only when we managing the risk level to ALARP. This procedure must be balanced with cost, time and difficulty.

Safety Evaluation of Regulations

Regulations provide safety. From this argument, already mentioned above, can be derived several other facts. The main is the principle that regulations are made for safety. Therefore it will be good this safety somehow evaluate, or quantify.

To qualify and quantify safety was invented the usage of safety indicators. Thanks to this evaluation the safety performance passes from the options of YES / NO answer to the question "How much?", which is related to the transition to performance based oversight. For this it is necessary to introduce the performance based indicators (PBI).

But since the methodology of safety indicators based on the performance is nowhere united, the resulting implementation, usage and also the creation of the indicators depends at any single organization. Due to differences arising out of this state there are large number of indicators. For example Risk Based Indicators, Safety based indicators.

Overall, this evaluation is based on the processes of the organization where regulations are regarded only as input and evaluation focuses on the safety performance. However, the law itself must have a certain level of safety which can be evaluated. The level of safety of regulations is higher than the real level of safety, because of the disappearance of human factor in terms of non-compliance, whether error or violation. Regulations assume their compliance.

As already mentioned, a comprehensive evaluation of the rules would have almost no interpretive value. For this reason, it is appropriate to determine safety of only “narrow things", in this case approach.

Approach

Approach to landing is the most dangerous part of the flight and therefore stakeholders must pay more attention to draft regulations for ensuring the safe course of it. The main subjects can be identified in all processes involved in flight. From analysis of every part of these subjects could arise sub-characteristics and parameters, which are necessary to evaluate for the safety analysis.

Approach Characteristics and Parameters

Table 1 – Characteristics / Parameters vs. Evaluation (Evaluation has not given value, see Sec. 4.2)

Characteristic/Parameter	Evaluation
Approach type	
- Non precision - APV - Precision	
Approach procedure	
- ILS - GBAS - VOR - NDB - LLZ - LNAV - LNAV/VNAV - LPV	
Meteorological conditions	
- Visibility horizontally - Visibility vertically - Cloud base	
Decision height/altitude	
Aerodrome	
- Runway o Surface o Lighting ▪ Centreline ▪ Side-lines ▪ Threshold ▪ TDZ o Gradients o Elevation o Length o Width - Runway strip o Gradients o Elevation o Length	

- o Width
- Lights
  - o PAPI
  - o Approach lighting system
    - ▪ VFR night
    - ▪ Cat I.
    - ▪ Cat II./III.
- Equipment
- Meteo station
- Windsock
- Fence
- Ground radio navigation equipment
  - o ILS
  - o DME
  - o GBAS

Flight information service

- AFIS
- Providing traffic information
- Obtaining information
  - o Radio only
  - o Surveillance system
  - o Approval

Aircraft equipment

- VFR
  - o Basis
  - o Additional instruments
  - o GPS
  - o SBAS
- IFR
  - o The ability of the approach

Pilot

- Qualification
- Flight hours
- Experience

APPROACH SAFETY EVALUATION

It is possible to create a model of approach safety on the base of the evaluation of the weight of all the characteristics and parameters from the table above. It must be done in a way that will correspond to the effect of the parameter on safety. After applying this model to the current regulations it should be possible to determine the level of safety of regulations. But in this case appears one obstacle, it is: when the rules are respected, they provide safety at 100%. This would almost correspond to, in introduction mentioned, value $1*10^{-7}$, which is equal to 99.99999%. However, if we count all events affecting safety, the level of safety will start changing significantly, but still reach ~100%.

The current assessment of the safety level must be therefore based on the statistics and analysis of processes and determining those, in which is potential for error or violation. From this analysis is then possible to determine the risks and the highest risk indicate the safety of approach.

THE POSSIBILITY OF NOT FULFILLING THE REGULATIONS IN FORMAL ASPECTS

Regulatory basis of the European Union is quite extensive and inflexible, which significantly extends also into aviation regulations created by EASA. Individual Member States must follow these regulations and must ensure at least the same level of safety. National aviation authorities often interpret this legislation in their way and make it even stricter.

Regulations exist for quality assurance, which is in aviation defined as safe operations. Safety assessment mentioned above is based on the processes that form the activity. Therefore there is the possibility to ensure certain safety level with appropriately designed processes and without regulations.

Thus the result would be the next step above the Performance Based Oversight, which will have not oversighting implementation of regulations and performance of their compliance, but their nature and the way of ensuring that the nature of the regulations is fulfilled. This would remove any "remains" of compliance based oversight on formal rules as they would not be any longer required.

Table 2 – CBO vs. PBO vs. NBO

… Based Oversight	Rul es implemented	F ulfilment the regulation nature	H ow is it ensured?
Co mpliance	X		
Perf ormance	X	X	
Ne w		X	X

Conclusion

In this article is pointed out the challenge of determining the safety of regulations with regard to the human factor. The result of such evaluation would be able to change the way of aviation authorities' supervision, and thus create space for radical progress. This challenge is to change the type of supervising of aviation organizations. Already now the oversight moves from Compliance based to Performance based, which will certainly have a positive impact on safety, but it still means "strengthen oversight", which contains in itself the compliance. Move to the next level of supervision (no longer CBO) would allow greater flexibility of rules and automatic costs reduction. With this is related another challenge for organizations, which must ensure the safety, although legislation falls into the soft category. Also described in this article are two methods of evaluating the safety and is expected the permanent use of methods based on statistics of accidents and incidents.

Acknowledgements

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AIRCRAFT ICING CONDITIONS

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Abstract *– Modern transport aircraft have efficient anti-icing and de-icing systems. However, there can be occasions when the ice build-up is so severe that a system becomes less effective in keeping the skin clear of ice. Additionally there are instances where systems become inoperative. Knowledge of airframe icing characteristics can reduce possible hazards.*

Key words – icing accretion conditions, icing types, effects on aircraft, in-flight occurrence probability

I. INTRODUCTION

Icing is a meteorological phenomenon affecting flight of most aircraft. Even small deposits can have major effects on performance. The National Transportation Safety Board of the United States lists 4054 accidents/incidents between 1963 and 2006 with icing as a factor, causing a total of 2975 fatalities. 90% of these accidents involved general aviation. EASA between 1999 and 2008 reported 8 icing- related accidents resulting in 5 fatalities. Commercial aircraft have access to de-icing facilities and tend to climb through icing conditions regions in a relatively short time. In contrast, general aviation aircraft more often remain in cloud layers for a longer time resulting in ice accumulation on aircraft.

II. ICING CONDITIONS

Water in its liquid state is necessary for ice to form on an airframe. True airframe icing can only occur in cloud precipitation or fog. There will be no icing in the cirriform clouds as they are composed of ice crystals which will not adhere to an aircraft skin. Frost, which is ice crystals, can form by sublimation. The ambient temperature should be below 0 °C for ice to form and the same condition should apply to the airframe itself. However, instances have occurred where an aircraft has been flying at 9 km or more for some hours allowing a low fuel surface. In these circumstances ice can form at a lower level despite the ambient temperature being below 0 °C. This can also cause ice formation on the aircraft on the ground when there is rain, drizzle or fog and the aircraft has been on the ground for a short time.

The second essential condition for ice formation is presence of super-cooled water droplets. These water droplets stay liquid at temperatures as low as -45 °C. If an aircraft comes into contact with these droplets, the surface tension breaks down and the droplets start to freeze. The severity of the icing will partly depend on the size of the droplets. This is controlled by the cloud type and the temperature. Large super-cooled water droplets cannot occur in the general run of layered clouds such as Stratus because the basic cloud droplets are small. In Cu, Cb and Ns large basic cloud droplets can be expected. The temperature effects are governed by the fact that the lower the temperature the smaller the droplet that can exist in a super-cooled form. Therefore as the temperature in the cloud reduces from below 0 °C so the larger droplets progressively become ice crystals and thus cannot cause airframe icing. Different types of icing occur in dependence on the cloud type and the ambient temperature.

III. ICING TYPES

In-flight icing occurs when an aircraft flies through visible moisture, such as rain or cloud droplets, and the aircraft structure is below the freezing temperature of water. Three types of in-flight icing are clear, rime and mixed. A fourth type of icing, frost, accumulates when aircraft is on the ground.

CLEAR ICE

Clear ice occurs when the temperature is close the freezing (from 5 °C or 0 °C to -10 °C) , quite often in Cu and Cb clouds that are generating large raindrops. Clear ice looks as clear as glass; it is transparent and has a smooth surface. It is very tough and adheres strongly to the aircraft skin. After impact with a cold surface, the liquid portion of the super-cooled droplets flows out over the surface and gradually freezes into a smooth sheet of ice. Subsequent drops freeze on top of the ice and similarly flow over the surface, following the shape of the structure. Clear ice will only form in clouds where the basic droplets are large and thus it occurs in Cu, Cb or Ns clouds.

Clear ice can build up quickly, adding weight and disrupting the aerodynamic efficiency of the aircraft. Clear ice changes the shape of the wing and disrupts the airflow over and under the wing. Lift decreases and drag increase. As little as one centimeter of ice on the leading edge of a wing can reduce lift by 50%. Although clear ice is not as common as rime ice, clear ice that forms due to freezing rain or drizzle can build to hazardous amount in just a few minutes.

Rain ice is a type of clear ice which forms outside the cloud in rain. It can form ahead of a warm front or occlusion at low level and covers only a narrow range of altitudes. If rain is falling from Ns and there is an inversion with temperatures below 0 °C at the front, then the rain can become cooled. If an aircraft has been flying in this cold air for some time and therefore has a skin temperature below zero, the rain impacting on the airframe will cause clear ice to form. This can build up very rapidly causing the most dangerous form of icing. It is likely to occur on climb-out or on the approach and is therefore particularly hazardous. The rain ice conditions frequently occur in winter in Europe, particularly when the air ahead of the front is polar continental providing the low temperature air under the frontal surface.

Figure 12.2 Clear ice (source: NASA Lewis Research centre)

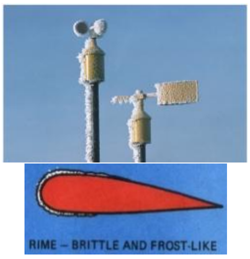

Figure 12.3 Rime ice (source: Météo France)

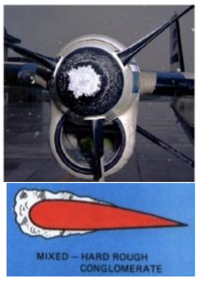

Figure 12.4 Mixed ice (source NASA-Lewis research Centre)

Figure 12.5 Hoar frost (source NASA-Lewis research Centre)

RIME ICE

Rime ice occurs at lower temperatures than clear ice, usually in the range from -10 °C to -45°C and is common in Stratus cloud and in freezing fog. Because the water droplets that create rime ice are colder than droplets that form clear ice, they contain less water; therefore the droplets freeze rapidly and have little liquid to spread over the aircraft surface. The rapid freezing of the small droplets gives rime ice its characteristic milky-white, almost opaque appearance with a light texture. It actually looks very much like a coating of light snow or frost, but is much harder and clings tenaciously to the surface.

Rime ice rarely adds much weight to an aircraft, but it can also cause aerodynamic problems for the wings. Although it does not spread all over the wing like clear ice, rime ice can be very difficult to melt off because it forms at such low temperatures. It can also cause some loss of aerofoil shape and air intakes can be affected.

MIXED ICE

Mixed ice is defined as a combination of rime and clear ice. It results when flying through area with temperatures around -10 °C and precipitation with varying droplet sizes. It can also form when icing occurs with wet snow. Mixed ice combines the worst of rime and clear ice and is often associated with Sc and Cb clouds.

HOAR FROST

Hoar frost is frost which can completely cover an airframe. It is a minor hazard compared with clear and rime ice.

The frost forms in clear air due to sublimation when air in contact with a cold airframe is cooled below dew point temperature and below 0 °C. The water vapour in the contact air then changes immediately to ice crystals. It is necessary for this frost to be cleared before take-off so that windscreens and canopies are clear, to obviate skin friction and a longer take-off run and also to stop radio interference which can occur with frost on aerials.

Hoar frost can form in flight if an aircraft has to make a sudden descent from a high level to a warm moist layer. The very cold airframe can then be in contact with a large amount of water vapor at the lower level and sublimation and frost results. It can also occur if an aircraft has been outside for the whole of a winter night and then early the next morning does a steep climb out through an inversion. The effects are not severe and the hoar frost can be cleared quickly.

PACK SNOW

This is icing due to a mixture of snow and super-cooled water droplets. It can block air intakes, undercarriage wells and any other aircraft openings. Generally, the wetter the snow, the more chance it has to stick to an aircraft. Wet snow has higher water content than dry snow (because it is not as cold) and will stick to almost everything. Wet snowflakes are also usually bigger than dry ones.

Wet snow will build up on things protruding into the air flow, such as pitot tubes, windshields, handles, wheel pants. It can even stick to the wings. Usually the major problem with an accumulation of wet snow on an airplane is weight. It is possible for an airplane to accumulate so much snow that it can no longer maintain level flight. The real danger when flying in snow is that, it can easily change into true icing conditions when a slightly colder temperature occurs.

CONDITIONS FOR ICING ACCRETION

The following forecast rules will help interpret the possibility of icing:

- In general, the colder the air temperature and wider the dew point spread, the less chance of icing,
- If the temperature is 0 °C to -7 °C and the dew point spread is greater than 2 °C, there is an 80% probability of no icing,
- If the temperature is from -8 °C to -15 °C and the dew point spread is greater than 3 °C, there is an 80% chance of no icing,
- If the temperature is below -22 °C, there is a 90% chance of no icing,
- Cumulus cloud created by solar heating have a 90% chance of light icing and icing will usually occur in the upper portion of the clouds,
- Moderate icing can be expected in freezing drizzle, when clouds are in a deep low-pressure area and in clouds within 100 km of a cold front,
- Severe icing can be expected in freezing rain.

If clouds are formed orographically, or if a cloud passes close to or over hills or mountains, then additional upcurrents can be caused by the wind against the hills. The result is larger droplets creation and heavier concentration of droplets. Cloud formed orographically in stable air will have a lowered freezing level which can be a few thousand feet below the forecast freezing level for the area, therefore lower than anticipated.

Icing intensity levels are relative because various aircraft accumulate and handle icing differently. Different types of aircraft accrete ice at different rates, depending on their airframe shapes and speed differences. For example, temperature rises with airspeed. High airspeeds create surface friction on the aerofoils, thus preventing ice accumulation. Consequently, pilots of high-performance jet airplanes might not reporting icing, but slower-moving aircraft flying through the same area might experience heavy ice accumulation. The main factor affecting the icing intensity is the amount of free water. The size of droplets is dependent on the cloud type and the temperature in cloud. Icing types intensity in dependence on droplets size and cloud type is defined as:

- **Moderate/severe clear** ice occurs in large Cu and Cb, smaller Cu, Ns with heap type characteristics and Ac castellanus. Super-cooled water droplets can only be large in Cu, Cb, and Ns and then only in the cloud temperature range 0 °C to – 20 °C.
- **Light/moderate rime ice**occurs in layer clouds but light to moderate is observed in Sc. In layer clouds small super-cooled water droplets are present from 0 °C to -10 °C.
- **Light rime ice** is usually present in layer clouds at temperatures from -10 °C to -45 °C, where super-cooled water droplets are very small.
- **Rime ice** – super-cooled water droplets are small in Cu, Cb, and Ns from -20 °C to -45 °C.
- **Nil** icing conditions are typical for Ci, Cs, Cc, where ice crystals will not adhere to the airframe.

Effects of icing

Airframe icing can cause a serious loss of performance, control and safety. The effects include the following:

- Aerodynamic - Ice tends to form in the greatest depth, on the leading edges of wings and tailplanes. The result is reduced lift and increased drag, weight, stalling speed and fuel consumption. Control surfaces can similarly be affected and thus control suffers. It is possible for pieces of ice to break off other fuselage surfaces and to jam between the control surface and the wing or tail.
- **Weight of ice** - In its severest form ice can adhere at a rate of 2.5 cm in 2 minutes. The weight plus the rate of formation will not be constant over an airframe. This will cause a wandering centre of gravity, instability and subsequent control difficulties. Ice on a propeller will inevitably form unevenly causing a weight differential on the blades. This leads to the engine rocking on its mountings and producing severe vibration.
- **Pitot/Static icing** - Ice can block pitot and static inlets causing readings of pressure instruments to be grossly in error. The instruments include altimeter, ASI, VSI and Machmeter.
- **Piston engine icing** - This icing occurs in the intake area and can restrict the flow of air to an engine. There is fuel icing which is caused by water in the fuel freezing in pipe bends thus reducing fuel flow to an engine. “Coring” can occur when very low temperatures cause oil in the oil cooler lines to become viscous and even to congeal. This results in only a small flow of oil along a pipe core which can cause engine seizure.
- **Carburettor icing** - This is caused by a lowering of the temperature inside the carburettor so that ice can form. The temperature can be reduced due to two causes: the evaporation of fuel which involves the absorption of latent heat from the metal internal parts and the cooling of the air by adiabatic expansion as it passes through the venture in the carburettor. Thus the inside of the carburettor can become very cold and any water droplets from cloud or fog in the inducted air can quickly form ice. The total reduction in temperature can be excess of 30 °C and therefore icing can occur in clear air at high temperatures if the relative humidity is 30% or more.
- **Turbine/Jet engine icing** - Ice in the first stage compressor blade area can form in the presence of super-cooled water droplets and generally the greater the engine revolutions the greater the icing. An accompanying high airspeed increases the mass of air entering the engine and the water thus droplet content. Another effect related to high engine revolutions is a pressure reduction inside the intake which can cause an adiabatic temperature fall of some 5 °C. Hence icing can occur at temperatures up to 5 °C. The clear air icing can occur with the aircraft on the ground if engines are run at high revolutions. Fuel inlet filters can be subject to icing when the fuel temperature is below 0 °C after long periods of flight. Engine power indications on the flight deck can be in error if there is ice on engine inlet pressure probes.
- **General** - A thin film of ice or ice crystals can cause skin friction resulting in a need for a longer take-off run. Windscreens and canopies can be obscured. Undercarriage doors can be iced up in the closed position causing delay in gear deployment. Ice on aerials can cause radio interference and the weight may cause a fixed aerial to break off. Aircraft with tail mounted engines can be damaged by ingress of ice breaking away from the wings.

IV. Conclusion

Severity of airframe icing is dependent on temperature, liquid water content, droplet size and vertical motion.The concentration of water droplets is higher in cumuliform clouds because of the stronger upcurrents, thus causing greater severity of icing. There should always be a greater concentration of droplets near the base of a cloud because of proximity of condensation level.

For icing to occur super-cooled water must be present in the atmosphere (liquid water droplets with a temperature below 0° C).The more super-cooled water there is present (Super-Cooled Liquid Water Content), the more significant is the icing risk. SLWC decreases with decreasing temperature.The larger the super-cooled water droplet, the more significant the risk.Only very small droplets seem to remain super-cooled below -20° C, hence the worst icing is likely between 0 C and -15 C.Super-cooled water droplets cannot exist with temperatures below -40° C.To determine the aircraft icing probability, it is necessary to interpret actual and forecast vertical profiles of the atmosphere, rainfall radar and satellite imagery together with knowledge and understanding of the characteristics of different types of cloud.

Airframe icing is a serious aviation hazard. The possible range of effects on an aircraft is reduction in the aerodynamic properties, change in flight performance, increase in weight and uneven loading, engine intakes become blocked, undercarriage retraction/extension problems, control surfaces jam or become stiff, pitot tubes become blocked, communications affected, vision impaired. Engine or piston icing occurs under conditions of high relative humidity close to freezing when the underpressure in a piston causes the humidity to condensate and freeze within the engine.

Aside from meteorological factors, the rate of ice build-up on the airframe also depends on the characteristics of the aircraft. Fast aircraft with thin wing cross-sections are more susceptible to deteriorating aerodynamics, and hence are more susceptible to ice accretion.

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COSTS CALLCULATION OF AIRSIDE OPERATIONAL ERRORS AND THEIR COSEQUENCES

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***Abstract** – The paper discusses cost structure of airside operational errors with focus on ramp handling processes. Costs can be spited into primary and secondary and calculation of both sub-groups is presented. Especially secondary costs are difficult to figure out as they comprise of various sub-categories that need to be taken into account.*

Key words – repair costs, delay costs, operational errors, costs calculation.

I. Introduction

Airlines spend billions of euros as consequences of operational errors every year. With air traffic constantly growing, this issue deserves more attention than ever.

Since it would be very difficult to figure out costs of operational errors of the whole aviation operation, this paper will focus on ground handling process, i.e. ramp operation hence the consequences of ramp operational errors. Even a little damage on aircraft (few square centimeters for instance) can cause significant financial costs, not just in terms of repair costs. In this case, cost structure is much more comprehensive. This issue will be discussed and presented later on.

Airlines pay high amount of attention to mitigating the safety operational risks. In order to decide whether the risk that caused particular error is worth of spending scares resources to mitigation effort, it is necessary to calculate the costs of particular ground handling errors as well as its consequences on the airline operation. The example of such a calculation will be provided within this paper.

II. Definitions

First off, it is necessary to define generic terms that will be used in this paper.

Enerror is the circumstance in which planned action fails to achieve the desired outcome.

An incident is an occurrence or event that interrupts normal procedure or precipitates a crisis.

An accident is an unexpected or undesirable event, especially one resulting in damage or harm.

III. Cost Structure

As it was stated at the beginning, error consequences consist of few sub-groups. They can be divided into the primary (repair) costs and secondary (delays) costs. The sum of these two categories creates the total costs of certain error. The source of the repair costs will be explained as well as delay cost calculation.

Primary Costs – Repair Costs

Each airline should have the database at its disposal which contains all repairs costs of the particular year. With this, there are no more difficulties in repair costs estimation. These costs could be very easily matched with database errors according to the date, type of aircraft and damage description. Labor costs were also involved in the final price.

Secondary Costs – Delay Costs

The unavailability of an aircraft is a tough situation for an airline. When damage occurs on the aircraft and the damage leads to a situation where the aircraft is grounded, the damaged aircraft must be replaced by another aircraft to continue the flight. If not, the flight might be cancelled.In order to prevent such situations, most airlines maintain a stand-by aircraft to replace the grounded aircraft. The costs to maintain a stand-by aircraft is estimated, according to the rule of thumb, 35 000 Euros per day for one narrow body aircraft cancellation and 125 000 Euros per day for wide body aircraft cancellation (together with indirect costs). While indirect costs are not claimed by the insurance, the cost for the repair of the damage is claimed via the insurance (direct costs).

On the top of that, there are another costs arising when the flight is delayed due to aircraft damage. In order to calculate the costs of time, the 2011 figures approved and issued by EUROCONTROL are presented. These are designed as a reference model for European delay costs that were incurred by airlines. We can split these costs into two basic stages. Delay costs can be represented as strategic (or planning costs), tactical (operational costs) and reactionary (or network costs).

Qualifying of these values is essential for SESAR (Single European Sky ATM Research) to be successful in order to the problems in European airspace. However, in this paper which focuses on apron error consequences, we will take into account just tactical costs. Strategic (planning) costs are irrelevant for our matter.

The outcome of these figures can be used mainly by airline operators to gain operationally helpful insights into apron safety and safety failure consequences. The result of these particular calculations is the European delay costs estimation, a pre-requisite of delay cost management. Delays are divided into different phases of flight (e.g. at-gate and taxing) and different aircraft types and costs scenarios. Various cost scenarios are used for different airports because consequences of an error can be significantly different at Schiphol Airport and Eindhoven Airport for example. The result can be also used by policy makers, airspace managers and designers, ground handling companies and airports itself.

The cost of delay is estimated separately for strategic and tactical delays. The first are also known as a “primary” delay costs because they represent original delays caused by one aircraft only. We already know that strategic costs are going to be equal to zero because we donot assume delays to be planned. Tactical costs are estimated for 5, 10, 15, 20, 25, 30, 45, 60, 75, 90, 105, 120, 150, 180, 210, 240 and 300 minutes intervals.

The “secondary”delay costs are caused by knock-on effect in the rest of the network. We assume that each particular delay of aircraft will create and equal delay reaction to the network level. This reaction is an exponential function. It means that small delay causes minimal reactionary costs, but each greater delay causes even greater reactionary delays costs. The secondary costs are also known as reactionary costs.

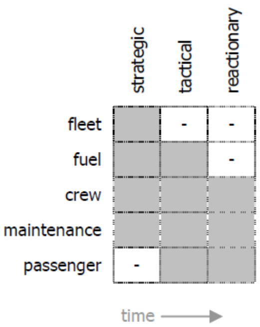

Figure 1 *- Primary and secondary costs [2]*

Figure above shows what cost types are assessed at primary (tactical) and secondary (reactionary) delays level. Five main costs categories are fleet, fuel, crew, maintenance and passengers.

Strategic and tactical costs are independent but reactionary costs are determined by airlines ability to recover from delay, for example, because of the amount of schedule buffer.There are two types of reactionary delays. The first type is rotational reactionary effect where the delay is spread over aircraft on subsequent legs. The second type is non-rotational reactionary effect were also other aircraft are influenced by the primary delay. Situation is explained in Figure 2.

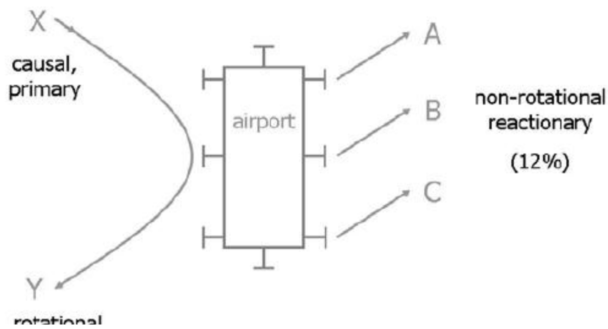

Figure 2 *- Rotational and non-rotational reactionary delays [2]*

In Europe, average reactionary delay per one minute of primary delay causes additional 0.8 minutes delay in the network. For the years 2008 and 2009, the ratio of rotational and non-rotational delay was 88:12. Reactionary delays shown in model above are split over more rotations. It is less possible that all reactionary delays would occur in a single lot. There are many different modes which are used for narrow-body aircraft or wide-body aircraft, and for different cost of fuel, passengers, crew and maintenance.

Delay costs are estimated for three different cost scenarios: low, base and high. These scenarios are designed to represent the wide range of costs for European operators. The base scenario is designed to reflect the average incident case. Calculations in this research were undertaken for these aircrafts: B 737-300, B737-400, B737-500, B737-800, B757-200, A319, A320, A321, AT43, AT72, B747-400 and B767-300. In the following sections, particular delay costs sub-categories will be closely examined.

IV. TACTICAL COSTS CALCULATIONS

The tactical costs of delay are normally calculated for four phases: at gate (APU and engines off), taxi, en-route and arrival management (sequencing). For this research only at-gate phase is relevant because it is the only phase performed at apron. As it was explained in Figure 1, there are five main costs categories. These categories are fleet, fuel, crew, maintenance and passengers. Each of them is calculated separately.

FUEL COSTS

Rates of fuel burn are taken into account just for three off-gate phases that are taxiing, en-route and arrival. The at-gate calculation assumes the aircraft engines and APU (Auxiliary Power Unit) are off. Furthermore, we do not consider fuel burn of apron equipment and vehicles nor emissions costs that are created. This is why we consider zero costs for fuel burn at at-gate phase.For other three scenarios costs of fuel burn (JET A1) are in Table 1.

Table 1 *- Three scenarios of fuel burn costs [2]*

Scenario	Cost of fuel / kg (Euros)
High	0.8
Base	0.6
Low	0.4

MAINTENANCE COSTS

A small part of the maintenance costs that are incurred by delayed flight refers to factors as the mechanical attrition of aircraft waiting at gates and personnel required for longer aircraft handling. Larger proportions of maintenance costs are the high intensity landing and takeoff cycle maintenance costs, but these costs are excluded from tactical costs. The cost calculation is based on values measured in 2002. These data were updated in 2010 using ICAO values, however just a small increase of 5% was applied during these change.

For at-gate turnaround only 20% of the off-block components attrition costs are assigned, zero power plant costs and zero stabling costs. That is why the tactical maintenance costs are relatively low compared to other factors.

The results of maintenance costs calculation are shown in Table 2 below. All of these costs were calibrated in such way that they are multiplied by the time each aircraft type normally spends at-gate.

Table 2 *- At-gate tactical maintenance costs in Euros per minute [2]*

Aircraft	Low scenario	Base scenario	High scenario
B733	0.2	0.4	0.6
B734	0.2	0.5	0.6
B735	0.2	0.4	0.5
B738	0.2	0.4	0.6
B752	0.3	0.6	0.7
B763	0.4	0.7	1.1
B744	0.8	1.0	1.1
A319	0.2	0.5	0.6
A320	0.2	0.4	0.6
A321	0.3	0.5	0.7
AT43	0.1	0.2	0.3
AT72	0.1	0.3	0.3

FLEET COSTS

Fleet costs represent the total costs of fleet financing. There are costs like depreciation, rentals and leases of aircrafts and handling equipment. All of them are determined by service hours. Since utilization of aircrafts has just very small effect on these costs, they are allocated only to the strategic phase. Tactical delay costs of fleet are thus taken to be zero.

CREW COSTS

Average pilots and flight attendants salaries were calculated in 2008 from various European airlines. Corresponding payment bills were calculated with real annual flight hours, sectors flown and overnight stopovers. Payment changes from 2008 until 2010 are considered and certain numbers corrected.

Pilots´ salaries generally increase by the size of aircraft and flight attendants´ salaries are almost the same across all aircraft types. It is custom in Europe that crew is paid with fixed salaries. Total required cabin crew numbers are given by the seats which are available in each particular aircraft.

The flight and cabin crew costs are cumulating with each additional minute over those planned at the strategic phase. The increase rate can be quiet different in various airlines, so three cost scenarios are introduced.

Low cost scenario – from a European perspective, for marginal crew costs incurred by airlines during delay, even delays in excess of an hour could result in no additional costs. For example, an at-gate delay would have no effect on the cost of crew paid by block hours worked as this payment mechanism is triggered off-blocks. An airborne delay will have no effect on the cost of crew paid by sectors flown as this payment mechanism is cycles-based. In both cases, a large proportion of pay would normally be fixed as basic salary, with per diem allowances. Zero cost is thus assigned to low cost scenario.

Base cost scenario – Although a delay experienced by an individual flight may have no immediate effect on the amount paid by the airline to the delayed crew, over a period of time (initially 28 consecutive days, then the calendar year), delays are likely to affect crews´ remaining flight and duty hours – limited by Regulation EC 1899/2006. Either overtime payments will be paid earlier than would have been the case without such delays (when the hours worked or duty threshold is reached) or out-of-hours crew will need to be covered by other/reserve crew. Prosy rates are modeled for the base scenario, using derived time-based salaries for flight and cabin crew, for each aircraft type. The base scenario costs, being proxy rates, are not the rates at which crew would actually be paid, but instead allow the determination of an equivalent marginal hour crew cost to the airline, based on realistic operational assumptions. They are averaged back over the whole year, allowing typical delay costs to be proportionally spread over crew paid at basic and overtime rates.

High cost scenario – It cannot be assumed that at-gate and off-gate hours do not generate additional costs to the airline for the base and high cost scenarios. Delay minutes are set at overtime rates for the high cost scenario.

Table 3 below, provides costs of aircraft crew during delays occurred either on the ground or airborne. Prices are set in Euros per minute.

Table 3 *- Ground and airborne tactical crew costs in Euros per minute [2]*

Aircraft	Low scenario	Base scenario	High scenario
B733	0	8.5	17.7
B734	0	8.2	17.8
B735	0	8.0	17.3
B738	0	9.0	19.5
B752	0	9.0	18.1
B763	0	12.9	34.6
B744	0	16.7	45.0
A319	0	7.3	15.2
A320	0	7.8	16.1
A321	0	7.8	16.1
AT43	0	5.6	11.5
AT72	0	6.1	13.0

PASSENGER COSTS

Passenger costs represent the value of time. As we researched the delay costs, there are no other costs that do not impact on the airline´s business such as full societal impact of delay. The costs of passenger delay can be divided into so called hard and soft costs.Hard costs – can be caused by factors such as passenger rebooking, cancelled flight compensation and other types of passenger care. It is quite difficult to ascribe all hard costs to certain flight because various accounting complications, but these named factors are at least in theory identifiable. Soft costs – represent damage to airline´s image. Even with no previous experience with particular airline, a passenger can perceive such event as unpunctual and choose another instead.

Longer passenger delay times leads to higher hard and soft costs per minute than the shorter ones. Recently, changes to hard and soft costs models have been introduced. New models of their distributions as a function of delay duration have been used to estimate costs. Together with typical seat allocations used by ICAO 2006, with aircraft data sample of more than 4 000 cases, LF (load factor) was applied for our different scenarios. Base scenarios are counted with 75% LF for narrow-bodies aircraft (60% low scenario, 90% high scenario) and 80% for wide-bodies aircrafts.

Using large datasets for passenger bookings and flight operations from a major US airline, Bratu and Barnhart [4] show how passenger-centric metrics are superior to flight-based metrics for assessing passenger delays. Primarily it is because the latter do not take account of replanted itineraries of passengers disrupted due to flight-leg cancellations and missed connections. These authors conclude that flight-leg delays severely underestimate passenger delays for hub-and-spoke airlines. Based on a model using 2005 US data, Sherry et al. concur that "flight delay data is a poor proxy for measuring passenger trip delays".

In order to distribute the hard costs as a function of delay duration, an empirical source of *care* costs (meal vouchers, hotel accommodation, tax-free vouchers, frequent-flyer programme miles and phone cards) was combined with a theoretical distribution of *reaccommodation* costs (rerouting/rebooking passengers, ticket reimbursements and compensation). Result of the combination we spoke earlier is shown in Figure 3 below.

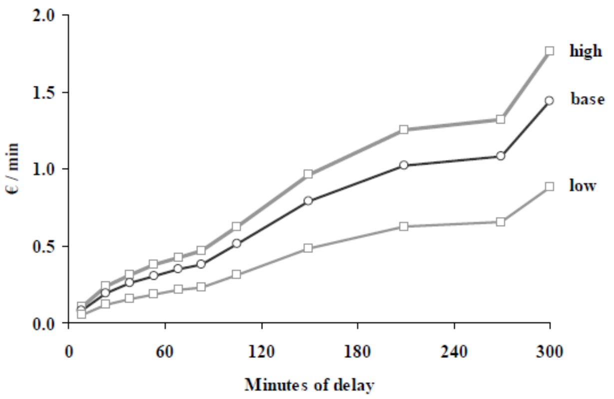

Figure 3 *- Passenger hard cost model by delay duration [2]*

Looking at previous Figure 3 it is clear that there are various deviations and it would be very hard to use such a curve for our purposes. Therefore, this power curve ($y = ax^b$) is derived in order to smooth the rates of change in cost per minute and to make the graph more tractable. The most of the delays occur at lower magnitudes so it is important not to make these numbers-under or over-estimated. 300 minutes interval is value used for capping the delay of wide-body rotations. After derivation there is a new curve that can be seen in Figure 4 below. For each scenario maximum deviation between original and derived curve do not exceed 2%.

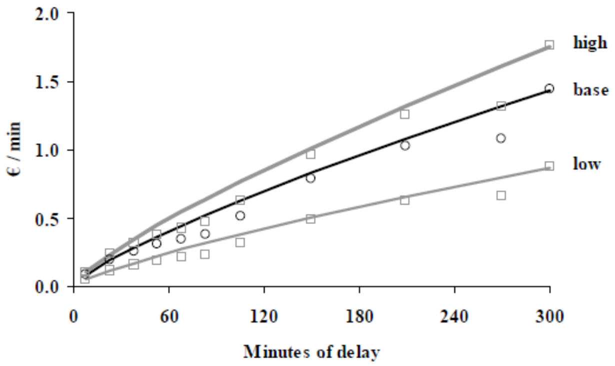

Figure 4 *- Power curve fit of passenger hard costs as a function of delay duration [2]*

Weighting the differences for each data point, along each curve, by the proportion of delays gives total increases from 0.9% in low scenario to 1.5% in high scenario. The average cost for hard passenger delay in base scenario is 0.183 Euro/min. In order to make data more readable graph was transferred into the Table 4 below

Table 4 *- Passenger hard costs of delay per minute[2]*

Delay (mins)	5	15	30	60	90	120	180	240	300
Low scenario	0.04	0.08	0.14	0.25	0.34	0.43	0.59	0.74	0.88
Base scenario	0.06	0.14	0.24	0.41	0.56	0.70	0.96	1.20	1.44
High scenario	0.07	0.17	0.29	0.50	0.68	0.85	1.17	1.47	1.75

Soft costs represent passenger dissatisfaction from an unpunctual airline operation and company loses its image and customer afterwards. Even passenger with flexible ticked, if arrives earlier at the airport, can choose another competitor instead of delayed flight on which he was booked.

European airline markets have become extensively price driven in the last years, with many traditional airlines that no longer serve free catering on short-haul flights. Low-cost carriers enjoy increasing market share all over the world. Increased use of internet has also helped to drive fares down and competition up. A discussion of UK researchers on delays also supports the idea that there has been no marked increase in delay sensitivity, during a period of worsening actual delay that we are experiencing.

It is expected by EUROCONTROL that the base scenario value of the soft costs of 0.18 Euro per passenger minute had not increased from 2004 until 2008. This is different to passenger hard costs which increase of 1.81% was measured from 2008 to 2010.

For distributing the soft costs of delay, logit function was used to express the propensity δ of a passenger switching from a given airline to some other choice after trips with given delay experiences.

$$\delta = \frac{1}{k(1 + e^{a - bt^c})} - k'$$

After this logit function was derived, following curve that can be seen in Figure 5 below was produced.

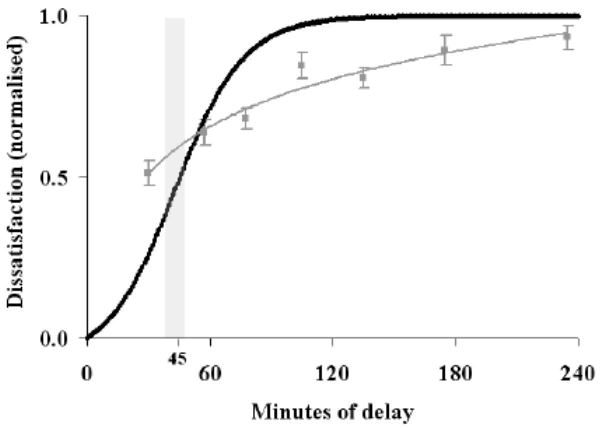

***Figure 5** - Passenger dissatisfaction as a function of delay duration [2]*

This S-curve has the desirable characteristics of maintaining a low switching propensity for some time, then rapidly increasing through a zone of *intolerance*, before leveling off after a duration of delay, beyond which the passenger is already very likely to switch airlines (for example) for the next trip. In order to make data more readable graph was transferred into the Table 5 below, using our three scenarios and delay band as defined before.

***Table 5** - Passenger soft costs of delay per minute [2]*

Delay (mins)	5	15	30	60	90	120	180	240	300
Low scenario	0.01	0.02	0.07	0.19	0.25	0.27	0.27	0.27	0.27
Base scenario	0.02	0.09	0.25	0.69	0.91	0.96	0.97	0.97	0.97
High scenario	0.03	0.10	0.28	0.77	1.01	1.06	1.08	1.08	1.08

V. Reactionary Costs Calculation

Rotational Costs

As explained at the beginning, there are two types of reactionary costs. Rotational reactionary delay is a network delay caused on the subsequent leg and non-rotational reactionary delay influences also other aircraft. Another division, whether the aircraft is narrow-body or wide-body, was applied as well. Reactionary delays are normally worse for longer delays and for other delays that occur at the beginning of each day because then the knock-on effects in the network can be spread to longer period. In average reactionary delay per one minute of primary delay causes additional 0.8 minutes of delay in Europe.

Narrow-body rotational model – narrow-body aircraft typically have around five rotations per day. If the first flight has a delay of approximately two hours, this may results into additional four hours of delay in total. Based on typical operational considerations the set of reactionary scenarios for narrow-body aircraft delay was established. These assumptions are summarized in the Table 6 that is shown below.

***Table 6** - Number of rotations over which narrowbody delay is distributed[2]*

Reactionary delay (hours)	Low	Base	High
0 < t ≤ 4	4	2	1
4 < t (capped)	4 x 1 hour	2 x 2 hour	1 x 4 hour

Wide-body rotational model – this model is much less clear compared to narrow-body model because wide-body aircraft rotations are not so easy predicted. It is because of different geographical scale and variability in operation. Wide-body aircraft may have quite long layovers compared to narrow-bodies. Time changes while crossing time zone can also play a role. Generally, because of longer flight times wide-bodies have fewer rotations in an operational day.The wide-body aircraft assumptions are summarized and shown in Table 7 below.

***Table 7** - Number of rotations over which widebody delay is distributed[2]*

Reactionary delay (hours)	Low	Base	High
0 < t ≤ 5	2	'1.5'	1
5 < t (capped)	2 x 2.5 hours	4hr20 + 0hr40	1 x 5 hour

Non-rotational Costs

The non-rotational model is much easier to calculate. It has been shown in Figure x that these delays represent 12% of all reactionary delays. I used this knowledge and with an easy calculation $primary\ delay * (1 - basic\ multiplier) * 12\%$ simply estimated the number of non-rotational reactionary minutes for each primary delay.

Based on the previous study, the multipliers that take into account the magnitude of primary delay were developed. In used model, all reactionary delays are treated as at-gate delay, either for onward flights from the same airport or on subsequent rotations. Following basic multipliers, showed in Table 8, were used to calculate overall reactionary costs.

***Table 8** - Basic reactionary multipliers by delay magnitude[2]*

Delay (mins)	5	15	30	60	90	120	180	240	300
Basic multiplier	1.49	1.67	1.94	2.47	3.01	3.54	4.61	5.67	6.74

VI. Delay Costs Calculation Summary

In this section final table for full delay costs is presented. Table includes all the tactical, rotational and non-rotational reactionary costs which was explained in the previous chapter. Calculation was made separately for three pre-defined scenarios: low, base and high. Low and high scenario tables are not included to avoid presenting a very crowded section here.

The summary can be found in the Table 9 below.

Table 9 *- At-gate base FULL delay costs in Euros per minute[2]*

Delay (mins)	5	15	30	60	90	120	180	240	300
B733	60	360	1 290	5 780	15 710	29 730	39 990	53 720	71 300
B734	70	400	1 430	6 510	17 820	33 670	45 260	60 680	80 310
B735	60	330	1 170	5 200	14 120	26 740	36 020	48 490	64 570
B738	70	440	1 580	7 200	19 730	37 270	50 050	66 970	88 410
B752	80	520	1 900	8 780	24 170	45 610	61 150	81 610	107 330
B763	150	880	3 130	14 510	39 380	84 200	119 910	149 510	186 220
B744	220	1 230	4 440	20 760	56 480	120 940	172 030	213 950	265 480
A319	60	370	1 310	5 960	16 330	30 880	41 560	55 820	74 070
A320	70	410	1 490	6 800	18 680	35 280	47 420	63 530	84 020
A321	70	470	1 770	8 150	22 490	42 460	56 980	76 140	100 320
AT43	30	160	520	2 160	5 730	10 940	15 040	20 900	29 020
AT72	40	190	670	2 900	7 780	14 800	20 160	27 630	37 690

VII. CONCLUSION

Airlines' expenses from aircraft damages and staff injuries are increasing with continuous growth of traffic. Results can be used by any airline in order to determine the total costs of particular apron error. When the costs will be determined, the decision making process whether to mitigate the risk that caused this error can take place.

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BEYOND VISUAL LINE OF SIGHT – FPV FLIGHT

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Abstract *– The aim of "first person view" flight is to see the Globe the way birds do. Even small RC controlled planes are able to take your eyes up in the skies using advanced video broadcasts from the sky. Overcoming the technical challenge still leaves questions to be solved. Beyond visual line of sight flight induces conflict with existing air traffic partners and possible loss of control generates new risk situation for people and property on the ground. Apart from that, privacy protection can be compromised by taking high resolution photos or videos without the permission of the owners.*

This paper intended to describe FPV flights and their risks - suggesting some solutions for FPV fans to find the right way for technical development and enjoy their hobby.

(free line)

Key words – first person view, safety, flight beyond visual line of sight.

(free line)

I. INTRODUCTION

"First Person View - FPV," that is, the sight of the person sitting at the front of an aircraft is now available without too much effort and financial expense due to easy access to this technology. The FPV is a great technical possibility that we owe to the modelers and amateurs experienced in radio technology and information technology assets. The "bottom-up" initiatives in the electronics industry quickly widely spread out and now offer a range of all the necessary elements of FPV flying.

When buying this technology, customers only receive instructions describing its specifications. They are supposed to explore everything else for themselves using their own creativity, or the help of their buddies in the modeling club. The Internet offers great opportunities through the mail forums – however, sometimes, at the same time; these forums reinforce the misconceptions and false ideas as well.

Those who are attracted to the category "extreme sports" flying – like bat wing base jumps from city buildings – FPV flying is trying to promote more "eerie" atmosphere. "Accomplishments" published in video splitters carry a growing threat to the population and to land and air transportation.

"The aviation safety aspects of application of the unmanned aircraft" research under The Hungarian *New Széchenyi Plan TÁMOP-4.2.1.B-11/2/KMR-2011-0001 critical infrastructure protection research program,* will just anticipate this challenge and propose solutions satisfying for the whole society.

The article first describes the key elements of the FPV techniques. Then, the application of critical cases is reviewed. Finally, suggestions for possible solutions will be made.

II. FPV TECHNOLOGY

FPV is currently one of the fastest extending activities involving RC aircrafts. FPV model aircraft have a small video camera and an analogous television transmitter onboard. It is flown by a live video down-link, commonly displayed on video goggles or a portable LCD screen. The pilot sees from the "first person's perspective", and does not even have to look at the model. As a result, FPV aircraft can be flown well beyond visual range, limited only by the range of the remote control and video transmitter.

The aircraft position (roll, pitch) as well as the artificial horizon, speed, altitude, GPS position and direction of returning the OSD - On Screen Display is shown. In critical situations – getting lost, hazy, foggy meteorological conditions, darkness and critical onboard systems failure – the special automatic flight control helps to return to the starting point.

The onboard robot can turn on features such as stabilization of the height and orientation. You can set the waypoints and a "fool proof" feature like the maximum angle of roll and pitch. In the picture, which is similar to modern fighter aircraft's "Head Up Display" - you can see the onboard battery level, engine speed, power consumption, received signal strength from the remote control and number of satellites. The signs and graphics can be configured according to needs.

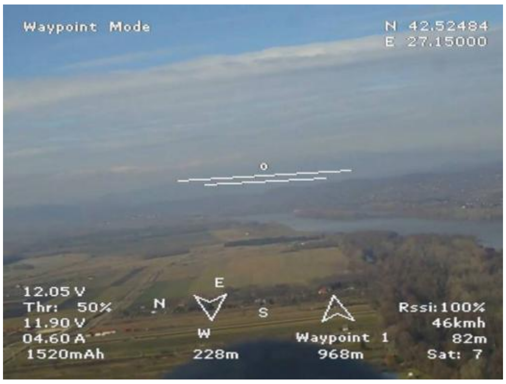

Figure 1 *– On Screen Display of C4S robot in waypoint mode*

The key element of FPV flying is a reliable two way radio communication. The bands are finite and the propagation is limited - only advanced (and expensive) tools can be used. The automatic tracking of directional antennas and "diversity" receivers can be competitive in spread spectrum remote control systems. The modeling department stores offer "ready to cook" solutions, but the selection, installation and use depends on the ingenuity of the user. The warnings are there for the best and most expensive device is "consequential damages in the event of equipment failure, the manufacturer is not liable."

A confused/lost control is the RC modeler's "bugbear" - which sooner or later almost everyone will meet. The manufacturers recommend "failsafe" feature on the receivers that the connection is restored preserving the last command or by setting "pre-programmed to servo" try to keep the plane in the air. Of course, this only reduces damage to property - it does not provide a solution to the machine "who and how to beat it"...

For the FPV aircraft optional equipment can be a GPS tracking that is sent to your phone coordinates of the location of a fall. Of course, it is not protected from liability by the "blind landing" aircraft caused - in connection with financial or tragic event.

The FPV flight surging popularity buoyed the modeler and "IT gurus" in the development of devices for flight safety. Along with many types of foreign manufacturers, "C4S autopilot and OSD" developed in Hungary is one of the most popular ones. The designers themselves are great modelers and seek the best solutions for the users.

Figure 2 *–Hungarian C4S robot*

The autopilot operates in four modes such as manual, stabilized, turning and flying home.

In manual mode the robot does not intervene, but in the background it is ready to take control when switching. The OSD is working.

In stabilized mode the autopilot keeps the machine in stable flight position. This mode is excellent for learning to fly.

The human pilot:

- Instructs the autopilot pitch and tilt angle of the machine you want

- Handles the throttle

The C4S autopilot:

- Controls the control surfaces

- Adjusts pitch and roll angle proportionally

- Limits the roll angle

- Limits the angle of climb

In waypoint mode the robot is flying the plane according to a pre-programmed route. The robot is starting to find Waypoint 1 and when it is reached, it switches to Waypoint 2, and so on. After getting the last point of the route the circle will start again.

Return home mode is automatically activated when the radio link is broken, but you can select this mode manually by switching on the radio as well. The plane will fly back to the start and begins circling at the preset height above the place of take off.

C4S is working very well – that was confirmed repeatedly by author of this paper and his colleagues. It provides security for the novice modelers and brings back the "lost" aircraft as well.

III. Black Sheeps

The FPV is a new dimension, which has long been preparing for the flight modeling society. But now this technology - which earlier used to be available only for those who were on NASA's budget - is available for a wide range of users. The options are very attractive and the technical and financial obstacles are getting smaller and smaller. "Gadgets" built by clever, enthusiastic amateurs are very welcome by the media, probably because it sounds great that amateurs can get in the 'Predator' footsteps. The YouTube and other video sharing's favorite themes are the do-it-yourself robotic aircraft.

Figure 2 *–FPV model is not a toy*

Prices vary from several hundred to several thousand dollars/Euros - depending on configuration. Sellers are interested in profit. Users can very rarely find real help in manuals; "how to use safely" – pages are mostly about warranty limitation. The examples where the "Black Sheeps" are flying around the cities, tunnels and under bridges do not help novices. [12][13][14]. In addition to technical failures, the most common problem is the loss of orientation.

Getting lost

A bird's-eye view is given for a ground pilot who is often amazed at the fact that he can't even recognize his own hometown - as the sky-view is so unconventional for humans. RC model guidance is not easy when you have to navigate through the eyes of a bird, but the loss of information can have serious consequences - the plane falls and can cause property or personal injury. This can happen even in the vicinity of airfields as well - where modeler could otherwise visually track the plane. In many cases, it has been shown that the FPV pilot -

once lost - is not able to find again his own aircraft in the air to continue the traditional flight regime.

To avoid such cases there is a simple solution: if some co-pilot visually follows the movement of the aircraft, and, if necessary, will help the FPV pilot. This is included in the recommendation of the Academy of Model Aeronautics "AMA Advanced Flight Systems Committee" Documents # 550 and # 560 and their revision in June of 2012 [1].

Let's see a few facts of this document:

"AMA modelers are not building or purchasing UAVs or drones whose flights are mission oriented, or flown beyond VLOS, or computer controlled for nearly their entire flight. AMA members are attracted to the recreational visual experience of FPV flying and the use of stabilization and autopilot systems to improve flight performance."[1] Page 2

Figure 3 *– Title picture from AMA FPV guidelines*

"AMA FPV flying involves two persons, a pilot and spotter, providing a higher level of situational awareness surrounding the model aircraft to identify and prevent conflicts or collisions.

R/C Pilots have direct transmitter control to activate or deactivate programmable stabilization or autopilot systems to recover an out of control model aircraft to level flight, maintain a heading, return an aircraft to a selected location, or initiate a programmed flight path.

Autopilot systems may be programmed to prevent a flyaway by safely returning a model aircraft to a selected base when a radio link is lost." [1] Page 2

The key element in this recommendation is "VLOS – visual line of sight limitation where the spotter and the FPV pilot are able to maintain visual contact with the aircraft and determine its orientation (without enhancements other than corrective lenses)". [1] Page 5

BEYOND THE VISUAL LINE OF SIGHT

In the following section, we will discuss the confidence of security provided by the autopilot, which may take some of the modelers in the wrong direction. An important finding is that ABILITY TO FLY BEYOND VLOS DOES NOT MEAN TO HAVE THE RIGHT TO DO SO.

Civilian customers and modelers who buy or build a FPV aircraft became closer to the 'big boys' games – military Drones, Unmanned Air Vehicles. The toy-stores do not limit purchases of long-distance radio communication, avionics and instruments. On the Internet you can find tips on how to increase the range of the radio link. Day by day, there are great distance and altitude records on YouTube [2][3]. The failures are often accompanied by fracture, rupture, fire and explosion [4][5][6]. The risk is much higher when failure is happening beyond the VLOS – where the uncontrolled airplane may cause unpredictable serious damages, injury or loss of lives.

Who will pay for loss? The AMA strictly refuses it: "As intentionally flying FPV aircraft beyond VLOS of the operator violates AMA Safety Code and documents 550 and 560, the AMA pilot should not rely on AMA insurance for coverage".[1] Page9

"YouTube FPV flyers" are unlikely to have any third party insurance. They may only hope for luck to avoid the penalty. Unfortunately, tragic events must occur so that the "outlaws" would disappear sooner or later.

PRIVACY PROTECTION SAFEGUARDS

According to AMA Advanced Flight Systems Committee document:

"The use of imaging technology for aerial surveillance with radio control model aircraft having the capability of obtaining high-resolution photographs and/or video, or using any types of sensors, for the collection, retention, or dissemination of surveillance data or information on individuals, homes, businesses, or property at locations where there is a reasonable expectation of privacy is strictly prohibited by the AMA unless written expressed permission is obtained from the individual property owners or managers." [1] Page 4

According to "Die Presse.com" article (24.04.2013.) – In Austria the law will now distinguish between those civilian airplane models that are remotely controlled about of people from the ground as a hobby in their spare time, and so-called "unmanned aerial vehicles." For the first group of model aircraft is explicitly stipulated that not for commercial purposes allowed to fly around. Moreover, they can be operated at a maximum within a radius of 500 meters, except the model remains at the airfield.

The remaining UAVs are further subdivided into two parts. In Class 1 visual contact with the control person must be given. In order for this aircraft may fly, they have to meet the operational requirements, which will come into power on the 1st January 2014.

In class 2 (without visual contact with the "pilots"), the use for commercial purposes is allowed for this type and stricter conditions for use will be provided. Rules similar to those for manned aircraft apply. Someone who controls such aircraft needs a pilot's license and a certificate stating the aircraft airworthiness. Finally, the air traffic rules as for the civilian manned aircraft must be respected.

Reporting requirement before shooting: When operating in classes 1 and 2 the operators such as pilots should maintain "most worth protecting confidentiality interests" of stakeholders in accordance with data protection law. This is especially true for all forms of photographic and film records that are made with such civilian drones. Already - before the recordings - must be made a mandatory report to the Data Protection Commission. [8]

FPV versus GA flight

Even the properly working FPV airplane can be dangerous when other General Aviation – GA vehicles collide in the air. As experience has shown - very few FPV pilots know what is happening in the airspace. They are preoccupied with their own problems - battery, radio communication, video quality and the others - and can not imagine what kind of trouble they can cause.

Check out on the internet: some FPV guys are visiting the same popular places such as sightseeing aircraft – Golden Gate, Grand Canyon, Niagara Falls – mostly without any permission and connection with local air traffic control authority. Pictures in Fig.4 grabbed from videos of one sightseeing aircraft and one of FPV piloted model downlink. That was the same route – thanks to heaven not the same time – around the nice castle of Visegrad in Hungary[9][10].

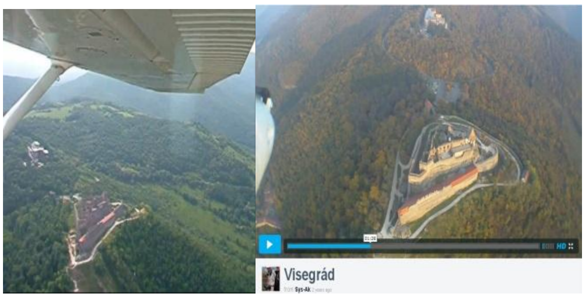

Figure 4 *– View from the CESSNA 172 and the FPV plane*

Let's calculate : when an FPV model of 7 kg weight flying at an airspeed of 50 km/h meets an airplane at with 150 km/h, the kinetic energy of the smashing model is equal to that of a high caliber rifle, that is,

$$0,5*7*(200/3,6)^2= 10802,47 \text{ Joule}$$

VFR pilots should continuously watch the airspace seeking the other – airplane size – object to avoid possible collision. The situation is similar as with big birds – no chance for airplane to avoid because the „partners" have very low visibility and are not cooperative. The common FPV model's sizes are from 0,1 up to 2-3 m and have no (any) TCAS capability. That is why those pirate FPV flights in uncontrolled airspace without permission are very dangerous; GA pilots are not prepared for managing the awkward situation.

IV. How to forward FPV flight

The previous sections mostly spoke about why we would need to ban FPV. Now let's take a look how we can help to find space for this highly evolving technology and very interesting and progressive technical improvements.

FPV flights do not have to be dangerous to the people and property neither on the earth's surface nor in the air. However, it should be noted that prohibition alone does not work. It is proven that FPV operations should be carried out in legalized forms. Aviation authorities shall determine and shall publish widely the structure within which FPV flights are allowed. This is an urgent task, because technology evolves faster than the law.

Some of our proposals to protect people and property in the vicinity of flights:

- On these model aircraft in any case there has to be an incombustible ID plate. The modelling associations should keep records of the identification data to know who is to take responsibility.
- Because GA is not allowed to fly below 150 m AGL (except for takeoff and landing), for the FPV planes there shall be designated a less than 150 meter high airspace. For the pilot wanting fly without special ATC permission it is forbidden to leave the VLOS airspace.
- If FPV pilots want to fly beyond visual range with the camera image showing where to go, this is definitely requires airspace and route permit. The pilot should have the same air traffic control contact, as if he would fly. Otherwise, a totally segregated and closed airspace should be provided to ensure that FPV does not conflict with another airplane.
- It would be good to conduct training for the operators and a certificate shall be given, because flying an uncertain and dangerous high-speed robot without any of the basic aeronautics knowledge - it's like "shooting at random, hoping that the shot will not hit anyone".
- The different races are a good opportunity to try FPV pilots in their own skills. The "IMAV - International Micro Air Vehicles" conference and competition as an example to learn how to find joy in our growing performances. Outdoor and indoor competitions provide adequate possibility for rivalry [11].

Figure 5 *– IMAV 2012 and three of the FPV planes*

"IMAV 2012" and similar events are not to show only the knowledge, but the industry and the military spheres have a keen interest in them. The observer's close eye follows the events and successful productions. Outstanding competitors can hope to be selected as a future employee.

V. Conclusion

This paper meant to present the problem and at the same time provide some solution - if it is possible. FPV modelling is a great opportunity for technical progress for amateurs, it should be supported. Many modellers - the best in its field - will later become professionals.

Now high-quality video cameras have small sizes. FPV models have a great opportunity to carry them. This is to be supported, but it should not cause hazard to others at the same time.

Negligence regarding observing the rules, which is now being present with some of the FPV–unit owners (I intentionally did NOT say pilot) – probably just a lack of knowledge and awareness – is alarming and needs to be change. Our task is not only to show the limitations, but also what is permitted - to help find the right path.

The modellers are required to better understand the "big planes" living space and needs. The different size, speed, and visibility of VFR flight may be a direct threat to life of GA pilots and passengers. However, GA pilots should be informed that recently small air vehicles may also occur in the air – their movement and behaviour is unpredictable.

FPV flying is a worldwide phenomenon - which is necessary to solve an international effort. The Internet can be an effective solution - if the instructional videos can be posted on the net - not just the "Black Sheep's".

"The aviation safety aspects of application of the unmanned aircraft" area of research at the Hungarian National University of Public Service covers the safety of complete unmanned aviation - including FPV planes. We explore the technical and organizational issues that lead to more safe and reliable systems.

The project was realized through the assistance of the European Union, with the co-financing of the European Social Fund. "Critical Infrastructure Protection Research TÁMOP-4.2.1.B-11/2/KMR-2011-0001" it enjoys the support.

NEW SZÉCHENYI PLAN

The author likes both FPV and GA flying and wishes to

PRESERVE THE SKY BLUE – for EVERYONE!

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COMPARISON OF THREE TYPES OF IMPERFECTIONS APPLIED DURING BUCKLING ANALYSIS OF CYLINDRICAL SHELL UNDER COMPRESSIVE LOAD

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Abstract *– Thin-walled structures like unstiffened cylindrical shells are prone to buckling. The imperfections, deviation from ideal shape, loading path or cutouts can considerably reduce buckling load of the structure. Three types of imperfections have been considered and compared– geometrical imperfection represented by single perturbation load approach and two types of cutouts, the circular and the rectangular one. Abaqus standard software package have been used for analysis of cylindrical shells made from composite material.*

Key words – buckling, composite, CFRP, FAE, FEM, Abaqus

I. INTRODUCTION

One of many applications of laminate composites is the cylindrical fairing of different parts of rockets, where the mass factor plays an important role. It has been calculated that the use of composite technology can lead to significant cost and mass reductions (20 % cost reduction and 40 % mass reduction compared to steel plates according to a study considering thrust frame fairings for the Ariane 5 rocket [1]).

Buckling of that cylindrical space vehicle structure is considered as critical and it must not arise. NASA published in 1968 design guidelines [2] for cylindrical rocket structure. The guidelines are based on very conservative measured data. Despite of the fact the guidelines are still valid.

Koiter [3] published in 1945 in his doctoral thesis theory which provides rational explanation of differences between analytical and experimental buckling analysis of unstiffened cylinders. Koiter revealed extreme sensitivity of buckling load on geometrical imperfections. The thesis was written in Dutch and translated into English by Riks in 1967 [3].

Since that time, many studies have been published about buckling of unstiffened cylinders. Degenhardt [4] compared analyses using finite element simulations affected by several types of imperfections (geometrical, material, boundary condition) with experimental investigation. The study described big differences around 30% between analysis and experiment.

Hühne introduced [5] promising concept calls “Single perturbation load approach” developed recently in DLR. The concept based on the fact that global buckling collapse of cylindrical shell starts at a one single buckle. The approach assumed that one single buckle initiated by lateral load (Figure 1) is the worst imperfection which leads to rapid decrease of the global carrying capacity of a cylinder. The concept was proved by many experiments and it correlates with finite element simulations.The Figure 2 [5] shows comparison of buckling load between numerical analysis and experiment.

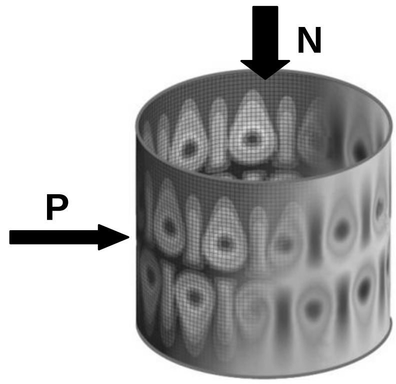

Figure 1 – Single perturbation load concept.

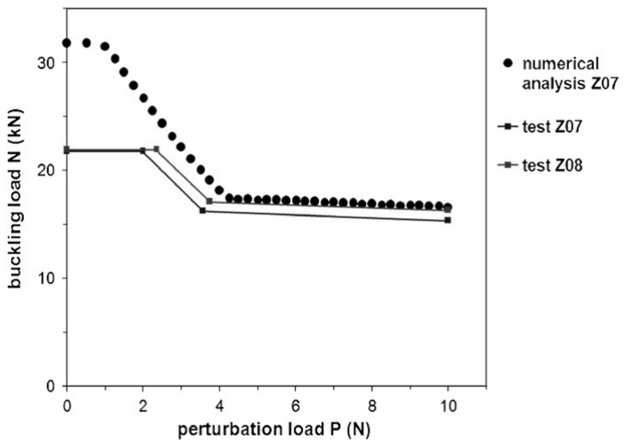

Figure 2 *– Comparison of numerical analysis with experiments.*

The scope of this article is to compare the single perturbation load applied on composite cylindrical shell with two types of cutout. The cutout can be regarded as type of imperfection. Two types of cutout have been considered the circular and rectangular one.

The two cylinders with diameter 400 mm and free length 800mm were analyzed. The first one was four-ply cylinder with axially symmetric laminate used in ESA study [7] (±24°, ±41°) and the second one was the six-ply cylinder with laminate ([±34°, ±0°, ±53°).It can be assumed that both these stacking sequencesare the most imperfection sensitive, becausethey are close to laminate which performs maximal buckling among all variants of possible axially symmetric stacking sequences [8].

Carbon fiber reinforced plastic prepreg tape was considered as material of the cylinders. The values from compressive loading tests have been selected for further analyses [7]. Table 1 shows complete list of values used for analytical calculation. The G_{23} value was approximated and Poisson's ratio was taken fromthe COCOMAT material testing.

Table 1 – Material properties used in the analyses

E_{11} [MPa]	157362
E_{22} [MPa]	10095
μ_{12} [-]	0.277
G_{12} [MPa]	5321
G_{13} [MPa]	5321
G_{23} [MPa]	4000

II. FEM MODEL

Abaqus CAE environment was used for the first model of cylinder. Tie constraints were applied for all nodes at both circular edges of cylinder. Controlling independent nodes were at the center of both circular end edges.

One of the central node at the centers of circular edges was fixed (all displacements and rotations were constrained) as initial boundary condition. Displacement control loading was applied on the second central node. Displacement acted in cylinder axis direction was applied, remaining DOF were fixed.

Abaqus/Standard, S4R – four nodes, reduced integrations shell elements with three integration points through each composite layer has been used. These elements implement a First Order Shear Deformation Theory (FSDT).

The number of elements over the cylinder has been extensively explored in [9] but for cylinders with R=250mm and free length 500mm with total number of elements 10800. This approach was recommended by [7, 9] as effective for buckling modeling of cylinders. Global element size for the mesh was ~ 8.5 mm. Constant ratio with respect to laminate thickness was maintained for all models. Hence, number of elements was increased for four ply cylinders with radius R=400mm and wall thickness t=0.5mm. Mesh with 10800 elements and global element size ~ 13.3 mm was used on six ply cylinders with wall thickness t=0.75mm.

Two types of parametric models in ABAQUS CAE environment have been created with circular and rectangular cutouts located in the middle free length of cylinders. Fine structured mesh has been used onto surfaces at cutout affected area. For both cutout types 40 elements (Figures 3, 4) were applied on cutout edges independently on cutout size. Number of elements on whole cylinder shells differed according to the cutout size.

Failure of composite material layers especially at the corner of the rectangular cutouts has been neglected.

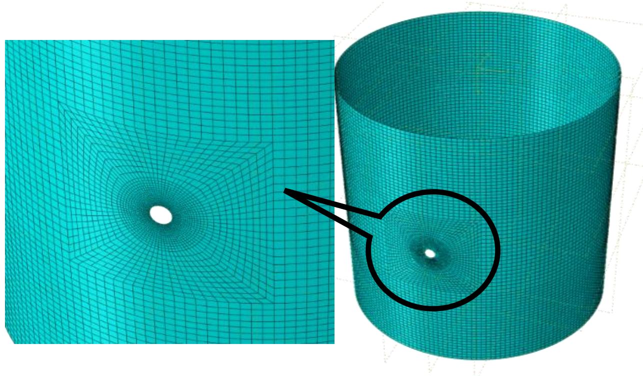

Figure 3 *– FE model with circular cutout*

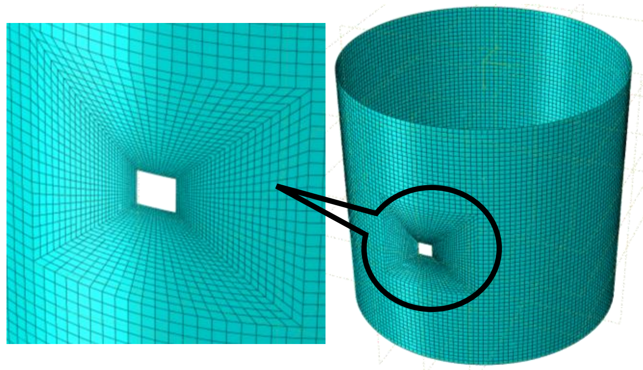

Figure 4 *– FE model with rectangular cutout*

III. ANALYSIS

Abaqus standard software package using Newton-Raphson method with artificial damping was used for the iterative nonlinear analysis procedure. The artificial damping value 4e-6 was taken from Steimüller [9]. The value was extensively utilized to validate cylinders with radius 250mm and wall thickness 0.5mm published in [7].

Single perturbation load approach design by Hühne [5, 6] has been used for imperfection sensitivity analysis. Characteristic perturbation – buckling load curve (P-N curve) (Figure 5) assembled from three lines (a, b, c on Figure 5) has been collected using FEM analyses results. The first horizontal line (a) corresponds with buckling load of geometrically perfect cylinder. The line (b) was created from other two selected points with P>0. Same strategy was used for line (c) where selected point had P>P1. The important P1 –N1 point was calculated in intersection of lines (b) and (c). Minimally five simulation results were necessary for one P-N curve. The Figure 5 shows an example of P-N curve using more than five numerical analysis results where points from other numerical results served as an accuracy check.

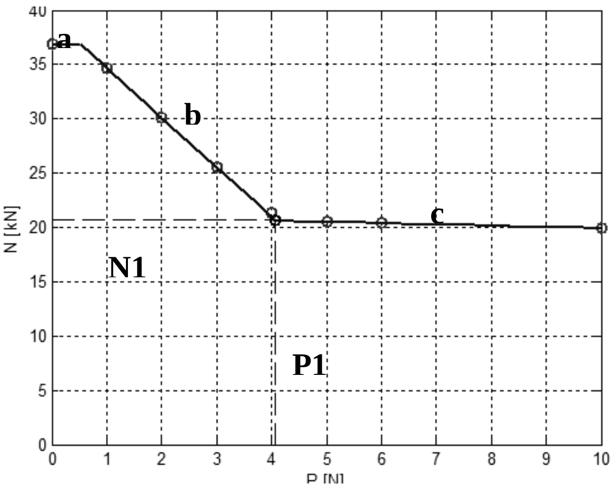

Figure 5 – An example of single perturbation approach characteristic curve

IV. Results

Eight simulations were executed for geometrically perfect cylinder and ten simulations were completed separately for six and four-ply cylinders and for both cutout shapes. The diameter of circular cutout and square edge of rectangular one serve as a characteristic dimension of cutouts. The characteristic curve with critical cutout dimension was reached for all simulations.

When the results are sorted out according to cutout shape Figure 6 and Figure 7 both curves are shifted between each other. The curves of six-ply cylinder result are moved to higher buckling loads. The critical cutout dimensions of both the results have similar value (~30mm circular cutouts resp. ~25 rectangular ones) independently on wall thickness of cylinder. According to the results, critical cutout dimension does not depend on laminate and wall thickness. But small numbers of results are available for conclusive evidence. Also both cylinders have the laminates with high buckling load and imperfection sensitivity. This trend could be explored more extensively and the first study would be applied on cylinder made from isotropic material.

The result curves in Figures 8 and 9 show cutout effect sorted out according to the cylinder types. The P-N results curve using the single perturbation load concepts were added. (The x-axis did not show consistent values and displayed perturbation load [N] and characteristic cutout dimensions [mm]. This is the reason for deformed shape of P-N curve in figures 2, 5. Generally speaking the figures describe an effect of three types of different geometrical imperfections on buckling loads for selected cylinders. Moreover the buckling loads for critical imperfection for all three imperfection types are close to one load level. It seems that N1 buckling load is a universal value distinctive for type of structure affected by geometrical imperfection without influence of geometrical imperfection type. This effect should be also explored more extensively for conclusive evidence.

V. Conclusion

The article outlines potential dependency between two types of cutouts and geometrical imperfections which was represented by single buckle created with lateral load. The presented outline should be further extensively investigated. The initial analysis with more examples can be applied on shells with isotropic material and after that composite materials can be included.

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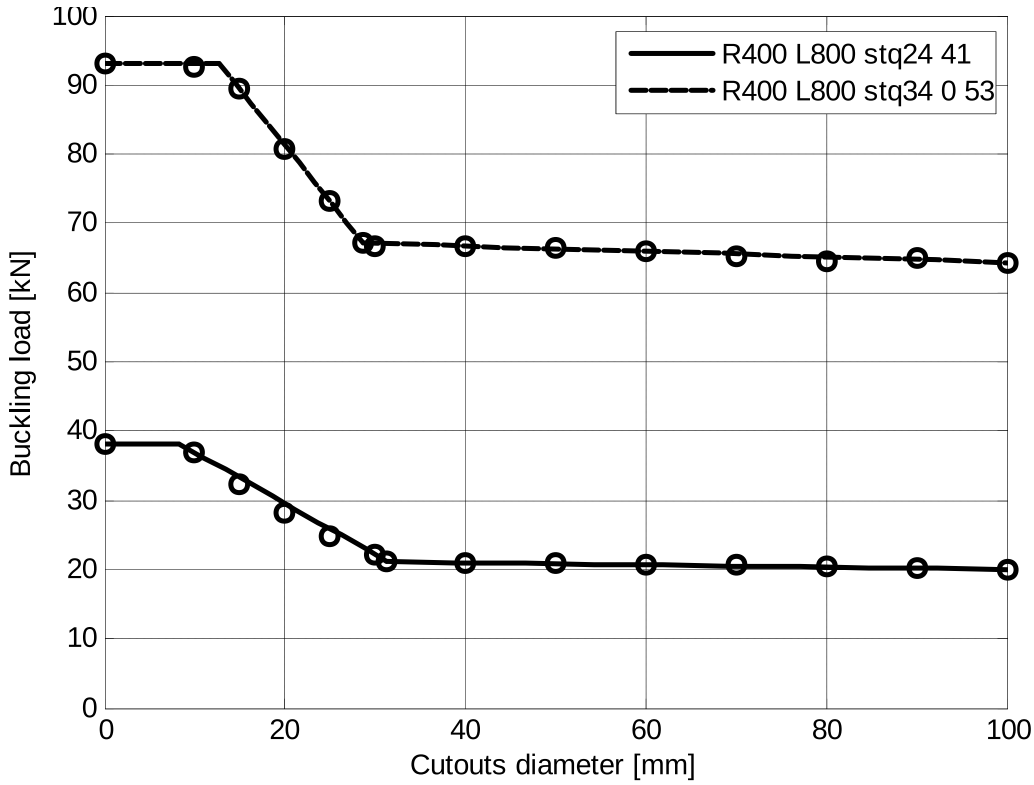

Figure 6 *– Effect of circular cutout on buckling load*

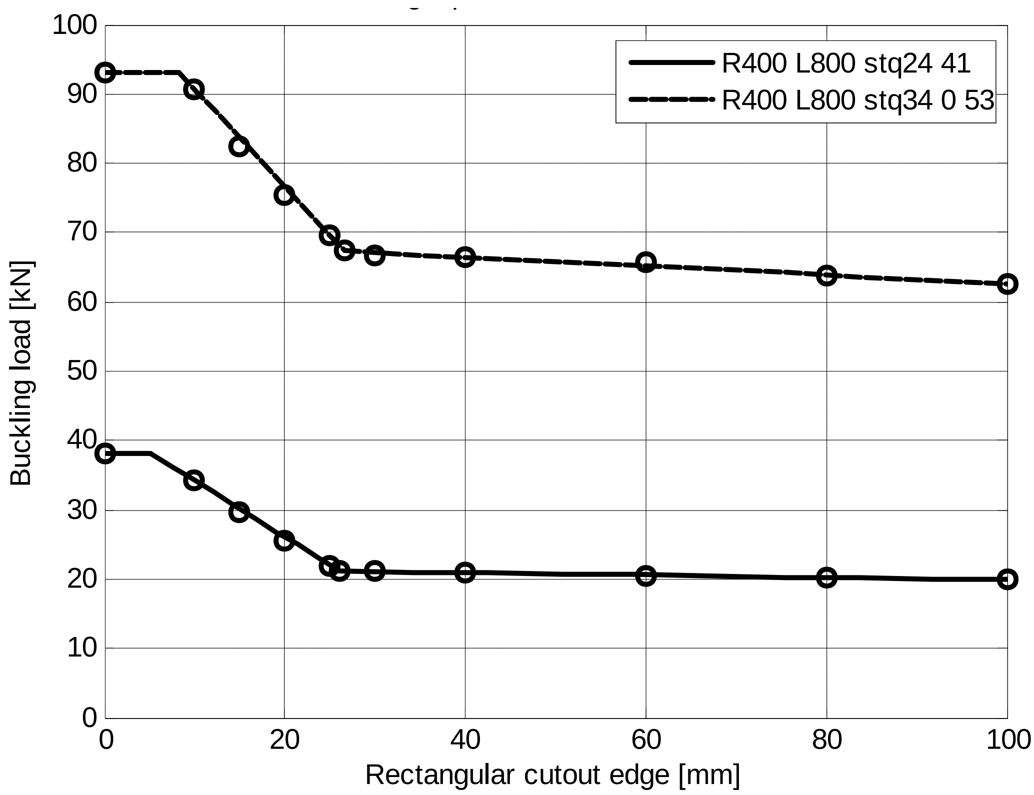

Figure 7 *– Effect of rectangular cutout on buckling load*

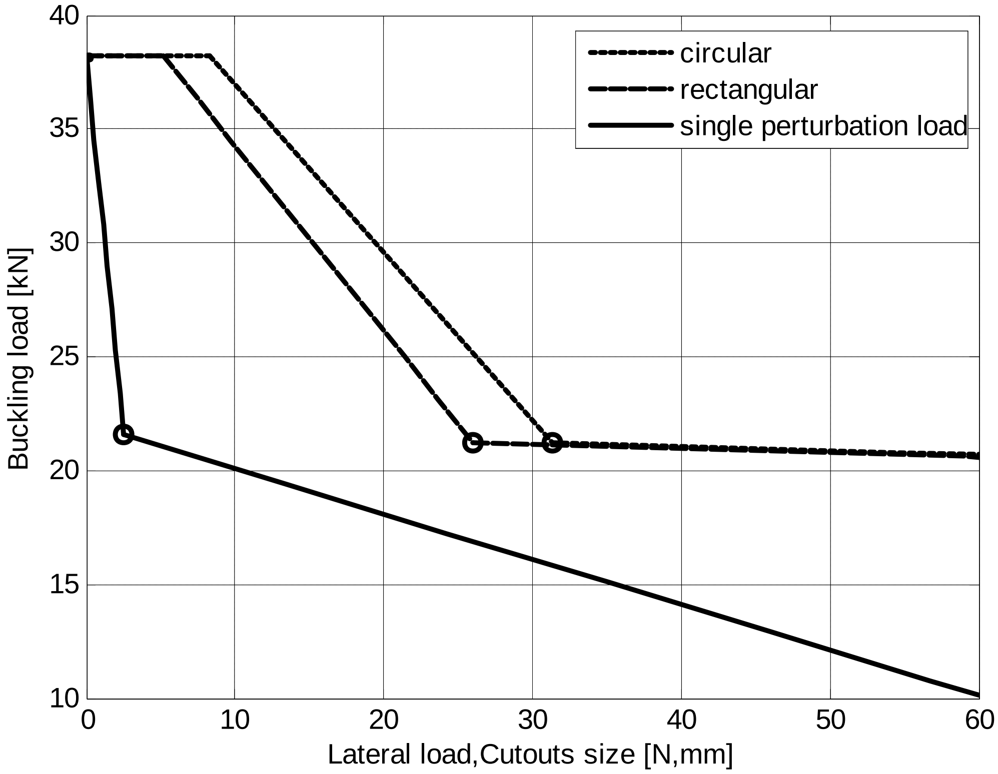

Figure 8 *– Effect of different geometrical imperfection on buckling load for four-ply cylinder*

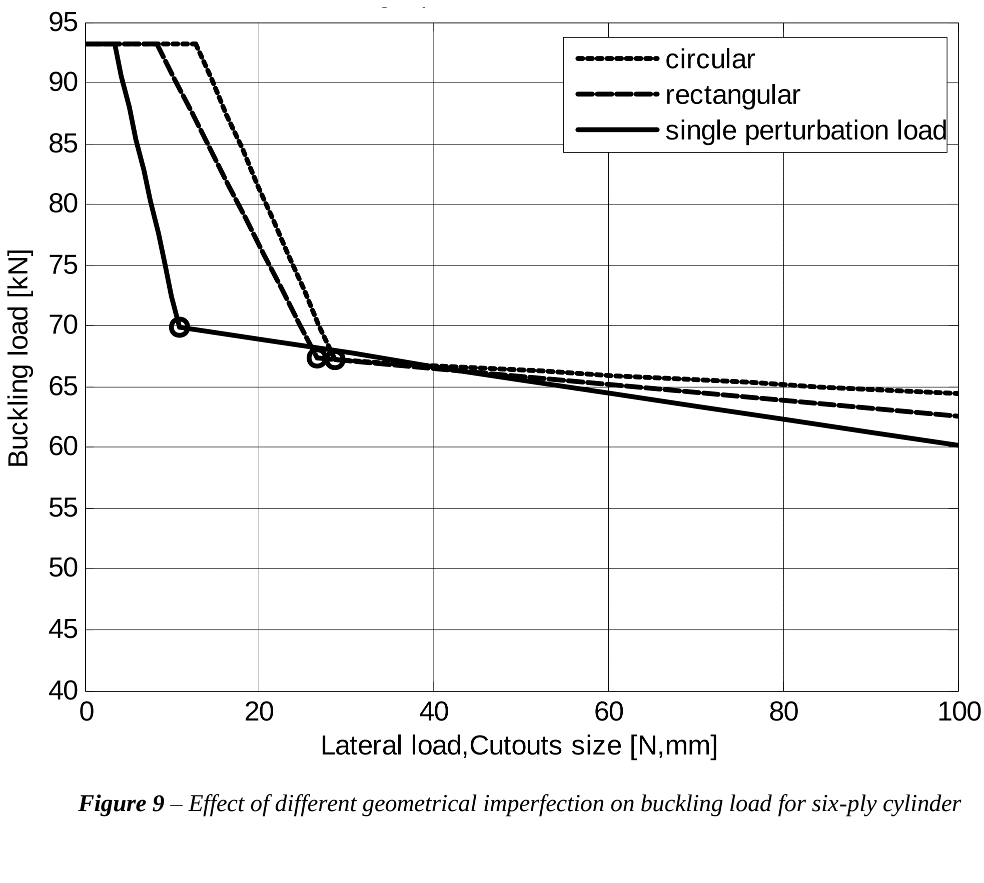

Figure 9 *– Effect of different geometrical imperfection on buckling load for six-ply cylinder*

APPLICATION OF GRADUATES OF UNIVERSITY OF ŽILINA,AIR TRANSPORT DEPARTMENT IN AIRLINE TRAVEL SERVICE

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Abstract *– The paper deals with application of Air Transport Department's alumni in the Travel Servise airline.*

Key words – Air Transport Department, Alumni, Travel Service.

I. THE AIRLINE COMPANY TRAVEL SERVICE

Airline Travel Service was established in 1997.

Travel Service a.s. is leader on the charter market in Czech Republic, Slovakia, Hungary and has a significant share in Poland.

In 2001 was established a subsidiary Travel Service Kft. in Hungary.

Outside the charter flights, since 2004 the regular lines are operated by Travel Service a.s. under the brand name Smart Wings and since 2007 aerotaxi category Business Jet are operated by Travel Service a.s. too.

In 2010 the company entered the Slovak market - the emergence of Travel Service a.s., Slovakia branch.

In 2012 was established Travel Service Poland.

The number of transported passengers in 2012: more than 3.5 million.

II. FLEET OF TRAVEL SERVICE

In 1997: the first commerce flight – type of aircraft Tu - 154 M.

Next year, the company entered Boeing 737-400 into the fleet.

Aircraft type Tu - 154 M ended in 1999.

In 2000, Travel Service included into the fleet Boeing 737-800.

Six years later, the company had 10 aircrafts - Boeing 737s.

In 2007, the company began with the private flights with the type Cessna 680 Citation Sovereign.

This year the company announced an order for the type Boeing 787 Dreamliner.

In 2008, the airline Travel Service uses for charter flights Boeing 767-300 ER.

In 2011, the overall condition of the fleet is 29 aircraft.

The current status of the fleet of the company Travel Service:

29 x Boeing 737-800

2 x Boeing 737-700

7 x Airbus A 320

3 x Cessna 680 Citation Sovereign.

III. NETWORK FLIGHTS AIRLINE TRAVEL SERVICE

The network of regular and charter lines of Travel Service a.s. covers the most important and popular destinations.

Network of lines of Smart Wings: Paris, Nice, Rome, Cagliari, Olbia, Catania, Lamezia Terme, Barcelona, Valencia, Malaga, Bilbao, Palma de Mallorca, Ibiza, Tenerife, Las Palmas, Heraklion, Chania, Corfu, Thesssaloniki, Kavala, Zakynthos , Kos, Kalamata, Preveza, Burgas, Split, Dubrovnik, Larnaca, Antalya, Dubai, Tel Aviv, etc.

Charter Lines:

- Long-haul destination: Bangkok, Varadero, Cancun, Punta Cana, Isla Margarita, Samana, Mombasa, Zanzibar, Colombo, Goa, Mauritius, etc.

-Medium- haul destinations : Egypt, Tunisia, Morocco, Israel, the Canary Islands, UAE, etc.

- Short-haul destinations: Italy, Spain, Greece, Turkey, Bulgaria, Croatia, France, Ireland, Portugal, etc.

The interesting thing is the annual exclusive flights under the name ,,Around the world", which the airline operates with the type of aircraft Boeing 737-800.

In accordance with the contract, the airline operates in the winter part with the fleet in Canada, in 2012 it was 10 Boeing 737-800. Also our crew and aircraft operating in the long term with Sunwing airlines, Oman Air, Jet 2 and in the past TUI, Ryanair, Singapore Airlines, Tajik Air, etc.

The airline Travel Service carry on charter flights not only clients of tour operators, flights are also ordered by renowned international companies, global, humanitarian and sports organizations. Travel Service is the official carrier of Czech national football team. Travel service provides air transportation of soldiers of different countries (the Nordic countries, Slovakia, Hungary) in foreign peacekeeping missions.

Travel Service, a.s. yearly travels to more than 250 destinatiaon worldwide..

Part of the flights are operated on airways where special proceedings (for example ETOPS) are required and many aerodromes have limited ground equipment and is located in broken relief with many obstacles. These destinations are categorized to category C –(for example Madeira, Insbruck, Samos).

This of course includes high requirements for flight crew training. Part of flight crew training are flights in conditions in low visibility (low visibility operations).

IV. Application of graduates of University of Žilina, The Department of Air Transport in Airline Travel Service

Aplication of graduates of University of Žilina, Deparment of air transport, is on flight operative and commerce technical department of our airline company.

Overall our airline company on B 737 : 266 pilots

- 131 captains and 135 co-pilots

- 10 pilots have qualification for TRE (type raiting examiner) – 6 of them are graduates of ZU (60%)

- 5 pilots have qualification TRI (type rating instructor) - 1of them is graduates of ZU (20%)

- 14 pilots have qualification LTI (line training instructor) – 9 of them are graduates of ZU (64%)

Actual state on base Bratislava (Slovak republic):

From overall number of captains are 80% graduates of ZU, 16% co-pilots are graduates of ZU.

Above written data shows that ŽU was and still remains important source of pilots for company Travel Service a.s..Another sources are graduates ČVUT, VVLŠ, and aviaton schools. Todays graduates of ŽU are forming significant part of management (Flight operations manager Ing. Pavel Veselý, Deputy flight operations manager Ing. Tomáš Nevole, Crew training Jaroslav Valigura) and instructor´s team of company.

V. Conclusion

University of Žilina is important source of flight crew for Travel Service. Practical pilot´s training is perfomed by stabile and experienced instructor´s team and according to it is possible to continue with next training in cases of chosen graduates. Bilateral cooperation of both subjects in upbringing future experts of civil aviation is rising by specialized lectures (observer´s flights for students and by enabling specialized practice in airline company. Department of air transport belongs to the oldest educational institutions of civil aviation of the world. Aplication of many graduates in practice is avidance that pedagogists are doing their work responsibly.

FLIGHT OPTIMIZATION IS A NECESSITY
FLIGHT PLANNING AND COST REDUCTION

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Abstract *– this paper describes flight optimization techniques and presents statistics and case study which demonstrate why flight optimization should be implemented in aircraft operators flight planning processes. With flight optimization aircraft operators can achieve reduction of fuel burnt, lesser flight times and therefore significant cost reduction.*

Key words – flight optimization, flight planning, economy, cost reduction, RAD, CFMU.

I. Introduction

In today's market situation, aircraft operators are facing growing fuel prices and at the same time tough competition pressures prices down. Flight planning optimization with right tools and company processes will help aircraft operators reduce their costs and gain advantage against their competitors. Every flight hour is burnt approximately 4 % of unnecessary extra fuel on board [3]. A 1% saving in fuel an A320 or B737-300 aircraft will result in a yearly reduction of fuel consumption by 100 metric tons and save aircraft operators approximately 120,000 USD per aircraft [3].

Reliable and accurate flight planning software can help aircraft operators minimize transport of the unnecessary fuel and reduce their operating costs.

II. Route construction

IFPS zone

Finding optimal route in IFPS zone is a tough task. CFMU(Central Flow Management Unit) restricts availability of airway segments trying to control increasing traffic in Europe. Route availability document (RAD) was introduced and aircraft operators are forced to respect that. RAD document [1] is published in PDF file and has 431 pages of text and approximately 3528 records.

When starting in or overflying IFPS zone operators have to file flight plan to the IFPS and then the flight plan is validated against several CFMU restrictions (RAD, CDR and CPLC). Result of the validation is acknowledgement or rejection of flight plan. If operator obtains rejection, the flight plan must be modified and then validated again. Today's state of restrictions saturation illustrates Table 1 and Figure 1. Worst situation is in Germany and Switzerland where more than 70% of upper airspace airway segments is somehow restricted.

Table 1 *– RAD restrictions saturation of airway segments*

country	airway segments count	RAD segments	perc	lower airspace perc	upper airspace perc
Czech Republic	439	239	54%	44%	64%
Slovakia	342	94	27%	24%	30%
Germany	3123	2096	**67%**	**62%**	**72%**
UK	2321	1243	54%	56%	51%
Poland	953	313	33%	34%	33%
Austria	715	352	49%	48%	51%
Hungary	546	144	26%	29%	25%
Switzerland	421	287	**68%**	**66%**	**71%**

Figure 1 *– RAD airway segments in IFPS zone, visualization: URANOS software*

Route construction could be very time consuming in this conditions. Even if you have simple auto router tool like Jeppesen Flightstar which is able to found shortest connection between two airports you have to go manually through validation -> rejection -> route modification -> validation - > ..... -> acknowledge cycle.

Other approach is to copy filed flight plans of other operators which can be very useful and efficient, but you must realize that restrictions are also time limited (CDR and RAD also). So you may copy flight plan which is flying around restrictions which is not applicable to your flight and because of that longer than optimal route is used (unnecessary expenses). CFMU proposed routes tool which is getting better, but still not ideal solution, can be also useful.

For effective flight planning advanced route finder tool is a must. Our flight planning solution URANOS provides advanced auto router technology REJNOK. REJNOK is using internal RAD database and automatically processes rejection messages and autocorrects find parameters. REJNOK can avoid restricted airway segments, CPLC (City Pair Level Capping) and even can solve restrictions by flight profile modification (underflow of restriction).

We have done measurements of 260 random airport (with SID&STAR defined) pairs and in 40% of pairs shortest connection obtains acknowledgement from CFMU and 60% obtains rejection. REJNOK auto router reach 96.15% success rate (CFMU acknowledgement) and average length is only 1.3% longer than shortest connection on the routes sample.

OPTIMIZATION BASED ON UPPER WIND FORECAST

If there is no air flow geographically shortest route is optimal but in real world we have to adapt to the meteorological situation. Considerable cost savings can be reached when routes are constructed with respect to actual upper wind forecasts.

According to our measurements of 100 randomly generated city pairs (see Figure 2), in **36% of cases** it is better to adapt to upper wind and choose longer route than geographically shortest. Calculations were done with Airbus A320 aircraft and summary of the results shows Table 2.

***Table 2**– results of upper wind route optimization*

average route length	1522 NM
average route length difference	1.2 %
average fuel saved	101.6 kg
average fuel saved percentage	1.6 %
best case fuel saved	547 kg
average time saved	2.8 min
average wind component difference	9.4 knots

***Figure 2** – randomly generated routes sample, visualization:URANOS software*

III. FLIGHT PROFILE OPTIMIZATION

STEP CLIMB

During the flight fuel is continuously burnt and aircraft weight is decreasing and therefore higher flight levels are reachable. For Airbus 319 flight from Prague to Gander (Canada) difference between flight with and without step climb is approximately 1100 kg which is almost **7% of trip fuel**.

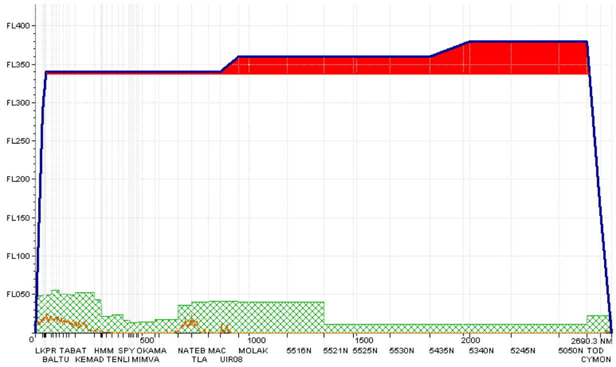

***Figure 3** – step climb, visualization: URANOS software*

PROFILE OPTIMIZATION BASED ON UPPER WIND FORECAST

Higher flight level not necessary means better fuel economy. Favourable air flow increases ground speed of aircraft and lower flight level might be better.

On flight from New York to Kingsville (USA) when southwest air flow strongly grows with altitude, for Airbus 319 and cruise mode mach .70 it is favourable to choose lower than weight optimal flight level. When lower flight level is used, 167 kg (1.7 %) can be saved of approximately 10000 kgof trip fuel and flight time can be reduced from 5 hours to 4 hours 45 minutes.

IV. ECONOMY AND FLIGHT PLANNING

As you can see in Figure 4 fuel prices are growing and fuel economy is getting more important than ever. If you want to adapt to this market situation you have to optimize operating costs. One way how to achieve that is flight planning optimization.

***Figure 4** – crude oil and fuel prices[2]*

Right company processes, properly trained dispatchers and advanced flight planning software are prerequisites for successful implementation of the flight optimization.

There are several requirements which advanced flight planning software have to meet:

- Accurate and reliable fuel and time calculations which is based on detailed aircraft performance data
- Horizontal and vertical route optimization
- Quick comparison of different variants of route and flight parameters with automatic costs calculation (time cost, fuel cost, overflight charges and terminal charges cost)
- Fuel tankering – calculation of profit/loss of extra fuel tankering
- Reduced contingency procedure – planned re-clearance in flight to enroute alternate
- Maximum payload calculation

V. Case study

Prague – Madrid, Embraer Legacy E-135

Two different routes were constructed – route VAR1 is geographically shortest with IFPS acknowledgement and route VAR2 optimized according upper wind forecast (IFPS ACK as well).

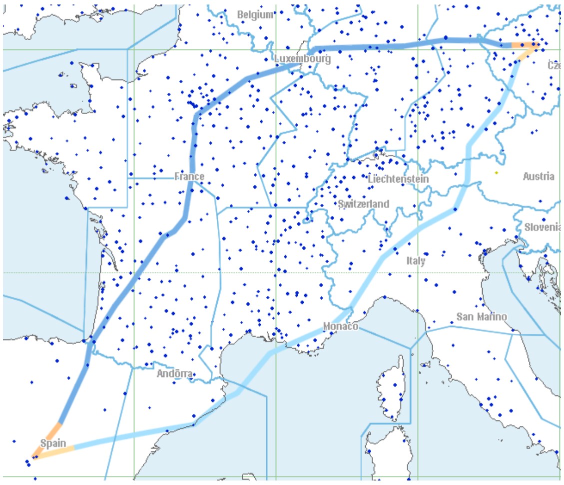

Figure 5 *– two variants of LKPR-LEMD route, dark one is optimized route VAR2, visualization: URANOS software*

Fuel calculations were done with long range, mach .74 and mach .80 cruise modes and 6 passengers on board. 1.2 USD per kg of fuel and 4000 USD variable costs per flight hour prices were used. The results of calculation are visualized in Figure 6 and as you can see best variant is optimized route VAR2 with mach .80 cruise mode.

Total cost (fuel + flight time + overflight charges) of VAR2 route with mach .80 is 15996 USD. Compared to VAR1 total savings are 1509 USD (= 17505 - 15996) which is 8.6% cost reduction. Summarization of calculation results shows Table 3.

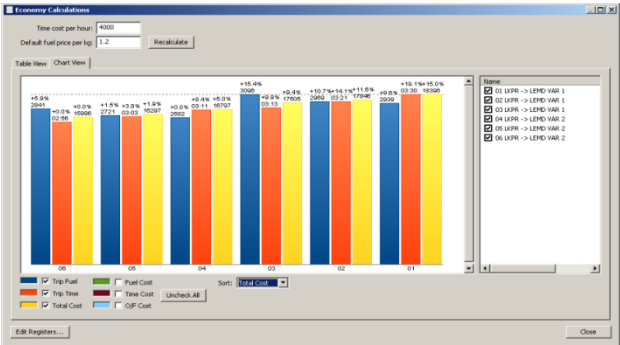

Figure 6 *– calculation resuls. Sorted by total costs, from left: VAR2 mach .80, VAR2 mach .74, VAR2 long-range, VAR1 mach .80, VAR1 mach .74, VAR1 long-range, visualization: economy module of URANOS software*

Table 3 *– results of variant calculations*

	VAR1 – shortest route	VAR2 – wind optimized	difference	perc
route length [NM]	1034	1057	23	2.2%
trip fuel [kg]	3097	2841	-256	-8.3%
trip time [minutes]	193	176	-17	-8.8%
overflight charges [USD]	1043	996	-47	-4.5%
total cost [USD]	17505	15996	-1509	**-8.6%**

VI. Conclusion

According to IATA Fuel Action Plan airlines that proactively manage fuel initiatives have a potential fuel savings of **9% to 17%** [3]. Our measurements and case studies prove that this potential savings can be achieved. Amount of a potential savings is so significant that every airliner should implement flight optimization into company processes.

NAV Flight Service's research, development and implementation of flight optimization into URANOS flight planning software have been realized thanks to the financial assistance provided by the Ministry of Industry and Trade of the Czech Republic from state budget (TIP project Flight Planning Optimization).

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THE CFD ANALYSIS OF MAGNETIC LEVITATION TAKE-OFF

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Abstract – Project Gabriel as many more innovative, "out of the box" ideas of great consequence besides to be examined with exhaustive economic awareness. Being a research for Project Gabriel this study attempts to find out whether the drag coefficient of an innovative take-off device could be reduced considerably or not. For this specific value could easily be correlated with many meaningful terms of our age such as energy consciousness, fuel consumption, flight safety or operation costs its importance is unquestionable. It is also the goal of this project to determine and analyse the velocity and pressure distribution around the body in aspect to reduce the drag force.In the first step we built the proper model in CAD software and made the requiring simplifications, then after defining the CFD model and all the known boundary conditions, jet engine characteristic we executed the numerical analysis getting a flow characteristic around the aircraft body and the take-off equipment. We assumed that in order to reduce the drag coefficient of the defined launcher-aircraft assembly an overlay designed with pretence of aerodynamic accuracy is necessitated. Based on CFD simulation of airflow against a non-optimised structure we can state that a minimum of 38% reduction can be expected. The analysis needs some further optimisation in cowling design and simulation accuracy so the prospective drop in value could hopefully rise beyond 50%. With the created flexible CFD model, other configurations could be examined for example cross-wind take-off, different engine setups, failures or the dragging effects of airflow in the narrow drain between the cart and the aircraft during take-off and landing as a future project.

Key words – Project Gabriel, European Union, Computational Fluid Dynamics (CFD), Budapest University of Technology and Economics, Department of Aeronautics Naval Architectures and Railway Vehicles, magnetic levitation take-off and landing, streamline, drag coefficient, cart, sledge, Airbus A320

I. INTRODUCTION

Gabriel is a European Union project that investigates magnetic levitation take-off and landing configurations for future airliners. The original demand that bred the idea was to reduce the inconvenient noise of airports so they can be built much closer to our cities saving passengers' time and millions of litres of fuel month-by-month. Another advantage of this innovative approach is the decrease in aircraft's weight which means we can carry more passengers or cargo. Hence the biggest strain of an aircraft – elevation from the ground – is no longer a function of its own, but the duty of the airport engineers are allowed to design engines optimised for lower performance. A smaller power unit has of course a reduced sonic emission and fuel consumption so we can fly our aircrafts vertically closer to the cities and fly them with more passengers or profitable loads. This innovative approach needs some new hardware systems planted on the airport and on the aircraft as well. The flying part of the equipment is the landing rods pretty similar to the ones used on marine helicopters called Harpoon-system only these must be pulled in during the flight. It has to be lighter than the original landing gears while enduring the same impact. The elements of the land part are the sledge that carries the aircraft on Harpoon rods anywhere at the airport might be either human or robotic-controlled, the cart on which the sledge can be docked from a ramp and a magnetic levitation lane on which the whole construction runs. The abbreviation CFD means Computational Fluid Dynamics. As a branch of fluid dynamics it uses numerical methods in order to analyse problems that involve fluid flows. Since it uses the Reynolds-averaged Navier-Stokes equations to do so we will have to discretize the flow space by creating a mesh that fits perfectly on the model but should we begin with building the proper model!

II. PREPARING THE GEOMETRY

In the need of finding or building a cart, a sledge and an aircraft model to be analyzed in CFD software we fortunately came by this CAD model of an Airbus A320 aircraft, which was well-detailed with easily recognizable dimensions thusly just perfect to demonstrate a European Union project:

Figure 1 *– Original model of Airbus A320*

PROBLEMS OF COMPLEXITY – SIMPLIFYING THE MODEL

We picked off the doors, windows and labels also making sure not to get any model-caused fault messages during the calculation and to make it relevantly faster after all. We avoided little details and small cells because the required flow space around the airplane is quite big. Obviously the more detailed a mesh is the higher calculating capacity and the more computational duration is needed to deal with the extended quantity of cells.For instance the aerials on the top of the fuselage would cause redundantly small cell-size hence a too long duration time. We simply removed the antennas because the turbulence caused by them would not have been of the order of the relevant turbulence caused by the cart, sledge and the fuselage.

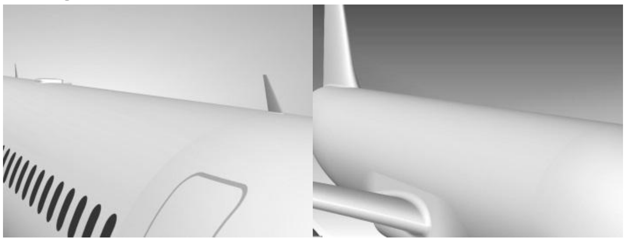


Figure 2 – Aerials and windows

The same problem occurred in the case of the engine nacelles. The small flat on the left was not an easy task to remove for the model did not have any history and though the nacelle was certainly made by a single revolved extrusion its profile was not easy to rebuild. In the end we used a donor part from the untouched right side and mirrored it to replace the cut one on the left. As we assumed the in- and outflow to be axial the compressor's first rotating blade wheel had to be replaced by a bare plane in order to define boundary conditions easily in the following.

Figure 3 – Engine nacelles

Even the exhaust tube of the Auxiliary Power Unit (APU) needed some modification. The reason was the same as earlier: our endeavour to avoid unnecessarily small sized cells and to make a planar face easing our job in CFD.

Figure 4 – APU exhaust

DESIGNING THE CART-SLEDGE ASSEMBLY

Afterwards creating the aircraft's model the auxiliary take-off and landing systems were modelled in virtue of our pre-calculations. Firstly the triangle-shaped cart with eight wheels of which the first four are manoeuvrable. This cart is responsible for the on-ground motion of the aircraft and it actually replaces gears' most important function: decreases the stress attacking the structure during landing and helps in take-off by increasing the angle of attack. It arrives onto the so called sledge on a ramp which sledge slides on a magnetic levitation field to speed up the airplane. Hereinafter we show the three-dimension models of each and the entire assembly with the aircraft but still without the cowling. The purpose of this model is to demonstrate how huge the drag can be in case we do not use any aerodynamic cover. We will run the CFD calculation on this model first simulating the heavily turbulent flow after the construction.

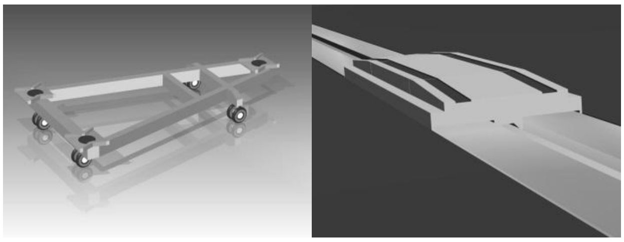


Figure 5 – Cart and Sledge

The device adjusts the aircraft against the wind of course and with its hydraulic system capable of increasing the angle of attack. The increased angle raises the wings' lift coefficient and helps the aircraft take off shorter or on a lower speed. Designing this hydraulic system would be a good issue for further development.

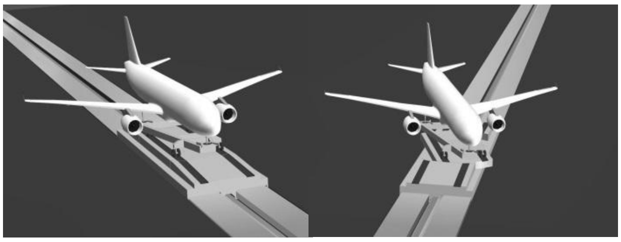


Figure 6 – Normal and crosswind-adaptive configuration

Done with the simulation of the naked structure we created a streamlined cover with the purpose of demonstrating a method to decrease the turbulence-caused drag. Two possibilities occurred to do so as follows and we chose the latter one to make in CAD and simulate because the first one seemed to be critical with the engines' nacelles.

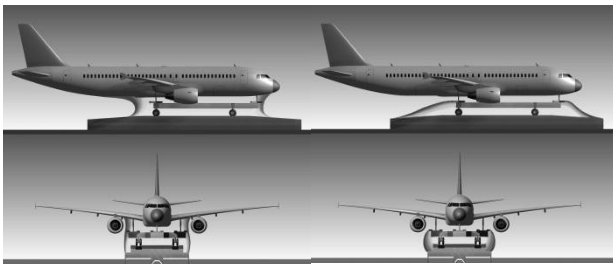


Figure 7 – Original cowling-design ideas

FINALLY WE GOT THE PREPARED ASSEMBLY

The simplified and built parts of the assemblyare now optimized for CFD simulation: here come the front-, top-, rear- and axonometric views of the entire aircraft-sledge-cart assembly ready for CFD analysis with and without the cowling:

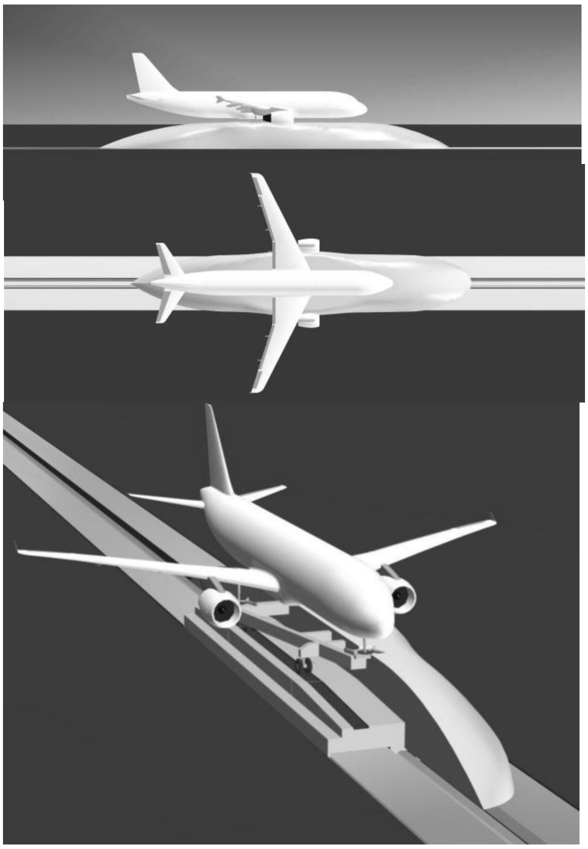


Figure 8 – Cowling overview

The hereinbefore mentioned idea was finally modelled as a mirrored multi-section swept protrusion. The model could be additionally refined as a thesis using feedback from the CFD simulation results of course but the main point is obvious based on even this approximation: A streamlined cover a so-called cowling is necessitated in order to have the flow less turbulent and decrease the drag coefficient during the take-off and landing procedures. Our next step is to show how the CFD simulation was executed.

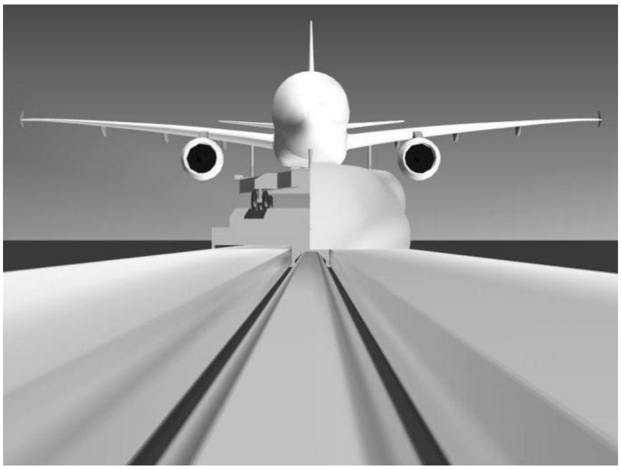


Figure 9 – Overview of different configurations

III. NUMERICAL ANALYSIS

The analysis of the take off configuration was done in Ansys CFX system. We have done investigation about two cases: The first is without the overlay and the second with the overlay. The aim of the investigation is to find out the differences of the flow characteristics between the two cases. The analysis was done with these simplified models and if the results are promising it is worthy to investigate more in this topic. The construction of the flow model can be seen in the figure 10.

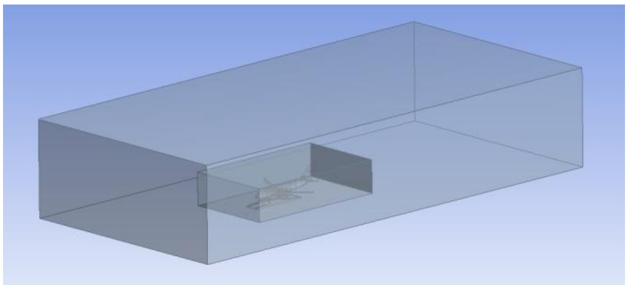


Figure 10 - Construction of the flow model

The model has two parts, an inner part, which contains the aircraft and has a mesh with a relative big density, and the second domain, which has a smaller density mesh in a big volume.The following table contains the characteristics of the mesh. As it can be seen the two cases approximately have the same number of mesh elements. The mashing was done in CFX-Mesh/ICAM.

	Cart Case	**Overlay Case**
Number of Nodes	**421291**	**448493**
Number of Elements	**214344**	**2207891**

Table 1 - The characteristics of the mesh

During the process of meshing it was an aspect to the two domains have a same mesh density in the interface. It was also an aspect to have an inflation boundary in as many surfaces as it possible. Because of the very complex geometry and the limits of the resources, the boundary layer was created in the main and important surfaces of the body. The mesh of the model can be seen in the figure 11.

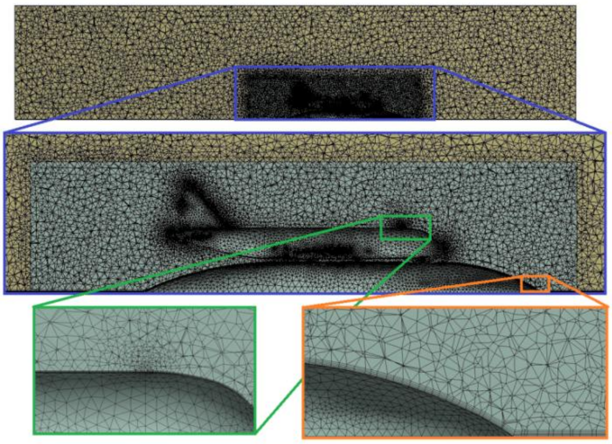


Figure 11 - The mesh of the model

The two domains and the interface can be seen in the Figure 12. The interface surface is necessary to connect the two domains.

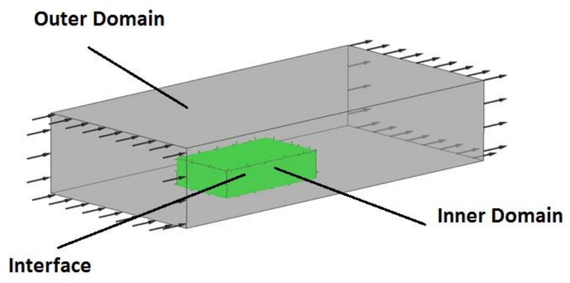


Figure 12 - The two domains and the interface

In the outer domain there are 4 different boundary condition: inlet, where the flow is entering the domain, outlet, where theflow is leaving, wall at the ground and symmetry at the other outer surfaces. Based on the previous simulations we asstimated thet the disturbances are neglectable at the borders.

In order to simulate the jet engine's effect there is two inlet and one outlet boundary condition in every engine. Where the air enters to the fan there is an outlet (because in our case it leaves the inner domain) and where the air quits there is one inlet for the primer flow, and another inlet for the secundary flow. The boundary conditions are summarized in the Figure 13.

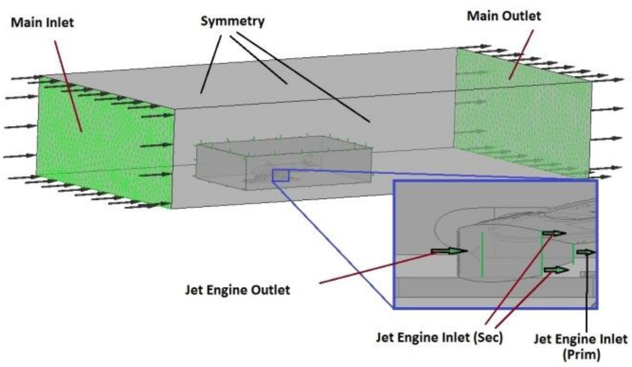


Figure 13 – The boundary conditions

The used turbulent model during the simulation is the k-epsilon turbulent model and because of the low velocities the used gas is ideal air.

There are more possibilities to use this model for other simulations. With the change of the boundary conditions there are available to simulate different cases of the take off and the land, just to mention the side wind or different engine mode. For the simulation of landing the overlay and the cart do not have a connection and the cart has a different angle, but because of the flexibility of the model it can be changed and simulated easily.

As the Figure 14 shows: the mass fraction and momentum residuum converged to 10^{-6} and the mass and energy imbalance to 0.

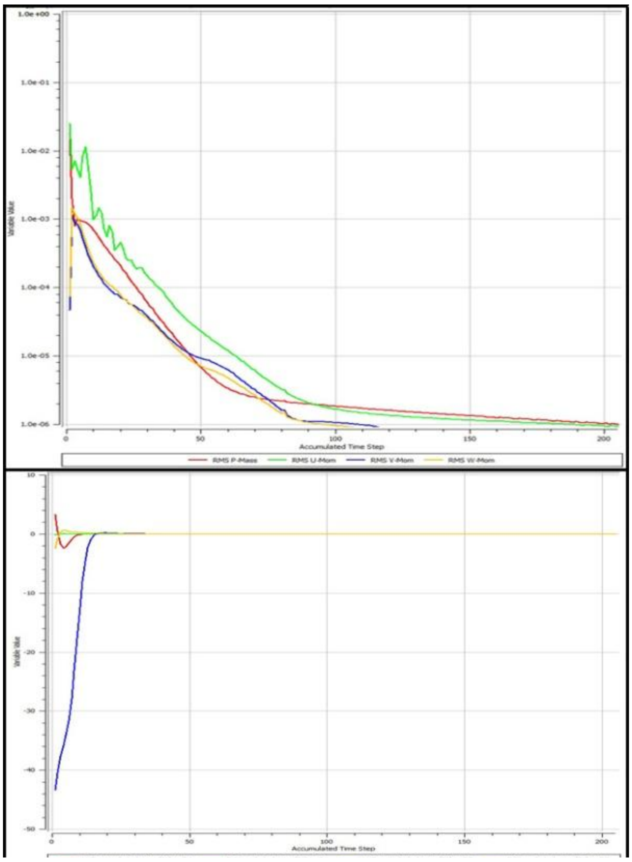


Figure 14 – Convergence curves

After the successful simulations the results of the two cases are presented here. In the Figure 15 the velocity distribution can be seen in the side view. It is easy to see that, in the overlay case the deceleration of the flow after the body is not as intensive as the case overlay.

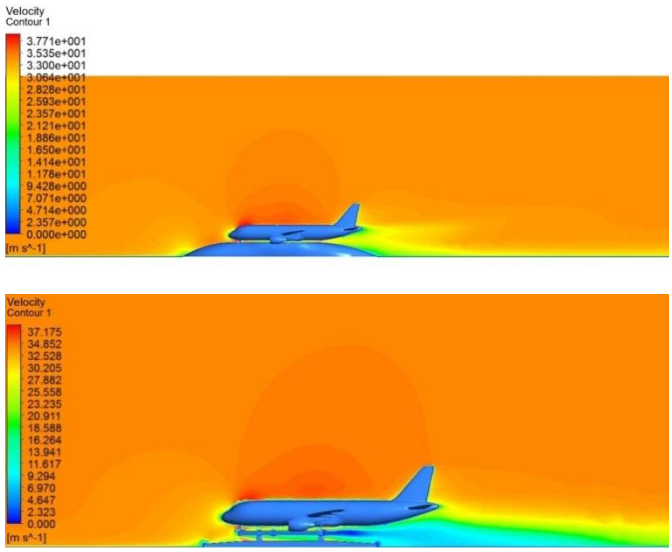
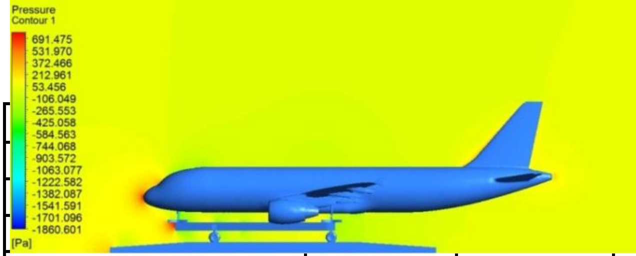


Figure 15 - Velocity distribution

In the figure 16 the pressure distribution can be seen in side view. It can be seen there is a stagnation point in both cases at the noise of the aircraft, but in the cart case, there is another one in the beginning of the cart.



Density (Kg/m^3)	1,178	1,178
Velocity (m/s)	34	34
Frontal area (m^2)	65,6	82,4
Drag coefficient (-)	0,594	0,355

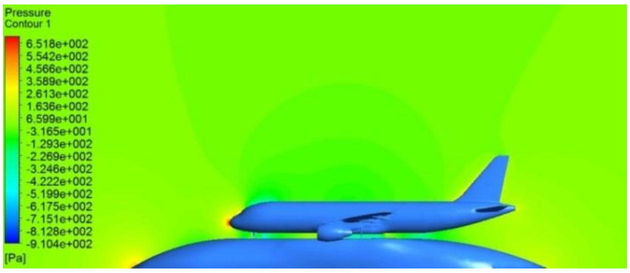


Figure 16 - Pressure distribution

In the figure 17 the Streamline distribution can be seen in side view. In the cart case there is a stall after the cart and in the overlay case the flow is more managed.

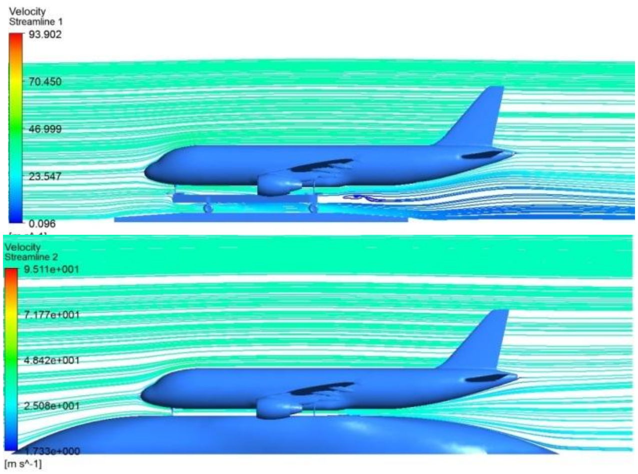


Figure 17 - Streamline distribution

The appeared drag forces and drag coefficients in the case cart and case overlay can be seen in the table 2.

Table 2 - The appeared drag forces and drag coefficients

IV. Conclusions

As conclusion we can state that comparing the configurations with and without the cowling the former one proved itself to be subservient in minimizing the drag, but for more accurate results further investigations are needed in the future. It is also required to redesign the concept of the overlay in accordance with the simulation results creating a streamlined and applicable outer surface paying respect tocritical distances from the engines and connection to the cart.For this short term work the mesh was satisfactory to prove that there is a vast difference between the two configurations and that it is worthy to do a more complex simulation with an improved mesh executing even a y+ and a mesh-convergence analysis.There are several opportunities in this project to continue with. For instance we could do an investigation about the stability change of the aircraft in case of crosswind or about the jet engines effects because of the leeside. Changing the jet engine’s setup there are possibilities to simulate different engine modes for example the fully operated, the no-load run or the failure of one engine both in the case of take-off and landing or we could observe the dragging effects of airflow in the narrow drain between the cart and the aircraft during take-off and landing as a future project.In summarywe can assume that in order to reduce the drag coefficient of the defined launcher-aircraft assembly an overlay designed with pretence of aerodynamic accuracy is necessitated. Based on CFD simulation of airflow against a non-optimised structure we can state that a minimum of 38% reduction can be expected.The examination needs further optimisation in cowling design and simulation accuracy so the prospective drop in value could hopefully rise beyond 50%.

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FLIGHT CHECKING OF GNSS APPROACH PROCEDURES

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Abstract *– This paper aims at aviation stakeholders familiarisation with concept of satellite based approach procedures, various types of procedures, augmentation possibilities and basic GNSS approach procedures flight checking principles.*

Key words – satellite, GNSS, approach, flight checking.

I. INTRODUCTION

GNSS approaches provide a cost efficient way to enable IFR procedures with lower minima on less exposed airfields. In addition, they can be used as a backup to ground based conventional navigation systems used for approach, such as NDB, VOR and ILS. We can divide these approaches into approach procedures with (APV) or without vertical guidance. The GNSS non-precision approaches without vertical guidance (LNAV) are already quite extensively implemented inlarge number of countries.

"APV procedures are being implemented world-wide in line with a resolution made at the ICAO 36th Assembly held in 2007." (1) This resolution urges ICAO member states to implement RNAV and PBN approaches in accordance to Performance based navigation manual (doc. 9613) and to implement approach procedures with vertical guidance for all instrument runway ends till 2016. The assembly also set intermediate milestones of 30% of instrument runway ends covered by 2010 and 70% by 2014.

In line with the above mentioned resolution, the Air traffic services of the Slovak Republic started to design and implement GNSS approach procedures ranging from LNAV to LPV. In the first stage they will focus on runways 22 and 31 at Bratislava M. R. Štefánik airport and both runway ends at Košice airport.

II. GNSS APPROACH TYPES

There are four types of GNSS approaches, of which two encompass vertical navigation (approach procedure with vertical guidance – APV) and two don't. The most basic type of GNSS approach, already used worldwide, is LNAV approach. This approach has the lowest required GNSS accuracy and can by flown using most aviation GNSS receivers. It is a non-precision approach and shall be conducted as a continuous descent final approach without step-downs.

LP (localizer performance) also provides only lateral guidance, but the required accuracy is much higher due to usage of satellite based augmentation system (SBAS), which will be covered in the next chapter devoted to GNSS augmentation. It is possible to lower the minima due to the increased accuracy, not only in the regulatory point of view, but often also due to smaller protection surfaces.

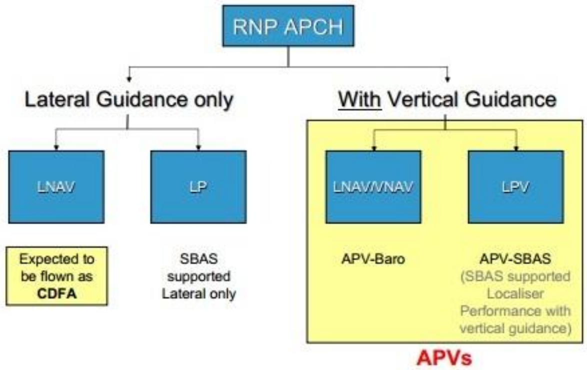

Figure 1 *– RNP approach types (2)*

The other two types of approach provide vertical guidance supplementing the lateral guidance of the previous simpler types. The vertical guidance is ILS look-alike and uses the same system of vertical and horizontal bars. This pilot indication is often implemented into the same primary flight instruments (CDI, EADI, EHSI, EFIS) as ILS indication.

The first APV type, LNAV/VNAV is based on the LNAV approach, together with its accuracy, but is augmented by inclusion of vertical guidance based on barometric altimeter. The major drawback of this type of approach is the altimeter error. The procedure is usually unusable below -15°C due to obstacle clearance.

On the other hand, LPV approach utilizes the accuracy of LP approach procedure combined with vertical guidance provided by GNSS system augmented by SBAS. It not only allows the lowest possible minima of the above mentioned approaches, but it also isn't influenced by the altimeter temperature error.

On figure 2 you can see the best case minima for various conventional and GNSS approach types. It can be seen that SBAS augmentation can provide the same minima level as ILS CAT I. In order to further decrease the minima, GBAS must be used. As the minima are defined for the best case scenario, obstacles must be considered in actual procedures design.

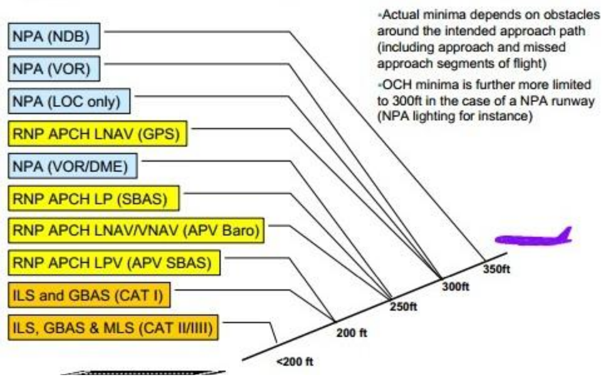

Figure 2 *– GNSS approach types minima (2)*

III. Principles of GNSS augmentation

There are three types of augmentation used in GNSS systems. The most basic type is ABAS (aircraft-based augmentation system)

"ABAS is achieved by features of the onboard equipment designed to overcome performance limitations of the GNSS constellations. The two systems currently in use are Receiver Autonomous Integrity Monitoring (RAIM) and the Aircraft Autonomous Integrity Monitor (AAIM). The RAIM algorithm performs a consistency check of the position solution: it requires a sufficient number of GPS satellites in view and a favourable geometric arrangement of these satellites." (3)

There also exist other two systems with greater need of outer assistance. These systems are known as SBAS (satellite based augmentation system) and GBAS (ground based augmentation system). SBAS is represented in the European region by EGNOS system.

"EGNOS (European Geostationary Navigation Overlay Service) is the European Satellite-Based Augmentation System (SBAS) that complements the GPS system. It disseminates, on the GPS L1 frequency, integrity signals in real-time, providing information on the health of the GPS constellation.

In addition, correction data improves the accuracy of the current GPS services from about 10 m to about 2 m. The EGNOS Service Area includes all European states and has the system-inherent capability to be extended to other regions, such as EU neighbouring countries, North Africa and more generally regions within the coverage of three geostationary satellites being used to transmit the EGNOS signal." (4)

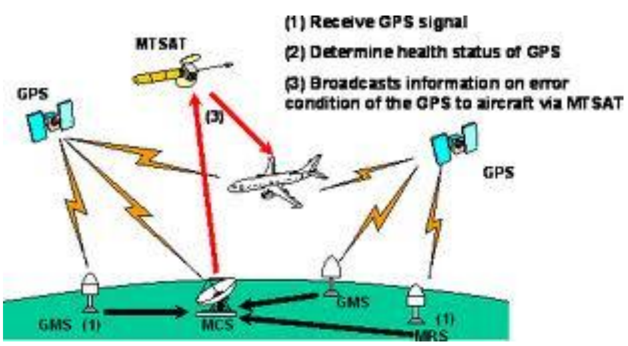

Figure 3 *– SBAS (5)*

"GBAS is a ground-based augmentation to GPS that focuses its service on the airport area (approximately a 20-30 mile radius) for precision approach, departure procedures, and terminal area operations. It broadcasts its correction message via a very high frequency (VHF) radio data link from a ground-based transmitter. GBAS will yield the extremely high accuracy, availability, and integrity necessary for Category I, II, and III precision approaches, and will provide the ability for flexible, curved approach paths. GBAS demonstrated accuracy is less than one meter in both the horizontal and vertical axis." (5)

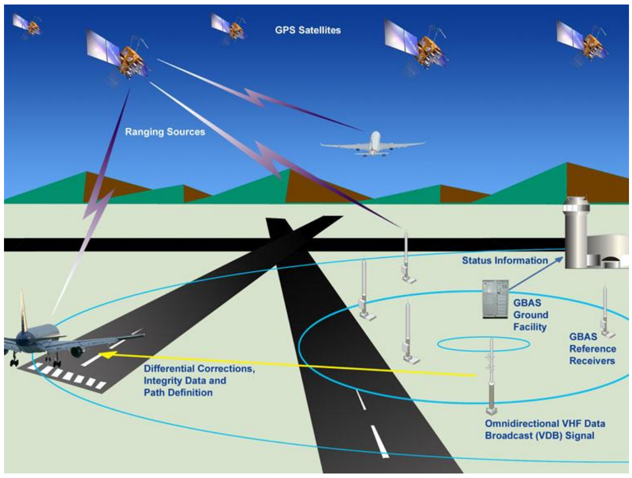

Figure 4 *– GBAS (5)*

ABAS is readily available in majority of aeronautical GNSS units. As was stated above, SBAS is starting its implementation in the form of EGNOS system in the EU area. On the other hand, GBAS procedures cannot work without ground based aids. Because of this, this type of augmentation is not so widely used.

IV. GNSS approach flight checking

Flight checking of GNSS approaches is specified in Annex 10 volume I and ICAO doc. 8071 - Manual on Testing of Radio Navigation Aids Volume II. "Testing is accomplished by dividing the GNSS architecture into the space-to-earth signals, from core satellite constellation(s), augmentation information and signals and procedure definition, including the integrity of the navigation database." (7)

When a State begins the introduction of GNSS flight procedures, an analysis should be performed of the capability of the particular GNSS architecture to provide the required performance to support the intended procedures. This state should continuously perform a suitable monitoring and assessment of the GNSS signal-in-space in order to detect any long-term trends which may affect GNSS performance within the airspace where GNSS-based operations are authorized.

Regarding flight inspection, there are four types of tests performed during the lifetime of a procedure:

- Site proving: A flight test conducted at the option of the responsible authority to determine the effects of the ground environment

- Commissioning: An extensive flight inspection to establish the validity of the procedure and augmentation signals
- Periodic: Flight inspection to confirm the validity of the procedure and augmentation signals on a regular basis
- Special: Flight inspection required to investigate suspected malfunctions, aircraft accidents,etc.

"GNSS flight inspection differs from conventional radio navigation aid inspection in that it does not attempt to verify the accuracy of the raw signals transmitted from the satellites. It is more concerned with verification of the associated procedures and of the radio environment in which the navigation signals are received. The only exception is GBAS where the coverage of the augmentation signal is verified using similar procedures to those used for terrestrial navigation aids." (7)

For flight checking of GNSS approach procedures, the location of the GNSS antenna is critical. Masking by aircraft surfaces should be minimized. If it is required to investigate interference, other adequate measurement equipment, as for example spectrum analyser, may also be necessary. For this purpose it is also viable to install a second GNSS antenna at the bottom of the inspection aircraft.

Although it is not required to record any GNSS parameters during flight inspection, some of them may provide clues in case of signal anomalies or interference occurrence. These parameters are for example cross track distance, active way-point, distance to active waypoint, bearing to active way-point, number of satellites visible, number of satellites tracked, carrier-to-noise density ratio, horizontal dilution of precision (HDOP), RAIM alarm, date and time and GNSS position.

In addition to the GNSS parameters, we can also record parameters of the aircraft flight test system. There is much fewer of them, among others XTKER (The across track error derived by calculating the position difference between the GNSS and the positioning system perpendicular to the direction of flight), ATKER (The along track error), WPDE (Way-point displacement error is the vector sum of the XTKER + ATKER), positioning system position data,tioning system time and operational status of the positioning system.

In case of interference occurrence, further tests shall be made in order to determine the following parameters or part of them sufficient to determine the extent of the problem and/or its origin (if these parameters are not already recorded by the test aircraft equipment).

- Receiver Autonomous Integrity Monitoring (RAIM) warning flag in order is to detect excessive pseudorange errors
- Receiver interference flag
- Signal-to-noise or signal-to-noise density ratio

The analysis may be supported by further spectrum analyser measurements.

V. Conclusion

GNSS approach procedures are a new phenomenon in the airspace of the Slovak Republic and we believe the University of Žilina with its equipment capabilities and knowledge can provide beneficial support in the process of GNSS procedures implementation and testing.

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INTRODUCTION TO SOFTWARE DEVELOPMENT FOR GNSS INFRASTRUCTURE ASSESSMENT SAFETY OF AIR NAVIGATION SERVICES

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Abstract – *Article presents introduction to software development background of GNSS infrastructure assessment. Primary objective is to support new final approach navigation applications and PBN implementation goals, which should be subjectof adequate planning by national ANSP responsible authority, national navigation strategy design in cooperation with all stakeholders, extensive pre-operational and operational GNSS service evaluation deployment.*

Key words – software, quality,GNSS, GPS, EGNOS, SIS, navigation

I. INTRODUCTION

Safety and effectiveness of air transport system are its primary quality parameters against which the system should be assessed. Within the context of these two attributes this article deals with one emerging issue of GNSS application operations under responsibility of national air navigation services.

In line with the recommendations in ICAO Annex 10 SARPs as well as the ICAO GNSS Manual, it is expected to cover GNSS infrastructure service verification by establishment of signal monitoring and evaluation. In general, ICAO Global Safety plan requires member states to effectively reporting and analysing of errors and incidents. Research in navigation infrastructure assessment is fast developing with the emerging GNSS system and applications.

Safety critical applications of any transport system are part of corresponding navigation services, wheatear in the air or on the sea. Evaluation of system operational performance for navigation applications and the design of the evaluation procedures is part of authors' long term research on the Institute of Aerospace Engineering, Brno University of Technology. Approach to the design of software for GNSS signal in space assessment is further presented in the article.

MOTIVATION

EUROCONTROL recognized advantage of research and development in GNSS monitoring several years ago. Today manages a network of around 30 GNSS receivers in Europe, none of which are deployed and operated in Czech or Slovak Republic. Its Navigation Steering Group remind on its 17 Meeting (19 April 2013, Brussels) the need "*of GNSS monitoring, whether it be for performance verification purposes to support GNSS approvals, for compliance with ICAO Annex 10/I recommendations on monitoring or for interference and anomaly detection"*. NSG meeting still aims to clarify objectives, roles and responsibilities for GNSS monitoring even though very familiar with Single European Sky legislation. EUROCONTROL also foresees iteration with DG MOVE (Directorate-General for Mobility and Transport) aiming at having the adequate legal provisions agreed by the Single Sky. EGNOS Performance Reporting Software proposes solution for GPS and EGNOS data analysis and navigation service levels evaluation in the area of FIR Praha.

II. THEORETICAL AND PRACTICAL ASPECTS OF SOFTWARE DEVELOPMENT

As the name of the article itself implies, the software for evaluation of the GPS and EGNOS supplied navigation quality for navigation applications it the application type of software. This means, it is type that is considered as "stand-alone", solving specific aviation needs. Its name is EGNOS Performance Reporting Software (EPRS).

SOFTWARE DEVELOPMENT PROCESS

As the requirements for avionic and navigation systems are documented, stable and author made a broad analysis of these, which enables reasonable schedules and definition of necessary resources, a *Waterfall model* for developmentprocess of the observation data evaluation tool. It has been used primarily as linear model that exists for a long time. It is build up on structured approach that contains four well explainable steps that are rigorously followed. That is *requirements analysis, design, system test and operation.* Today, same as in the article, combination with the other models is usual. Sever iterations in development have been done. As previously mentioned, a structured progression between defined phases is baseline. Each phase consists of a definite set of activities and deliverables that must be accomplished before the following phase can begin.

Author indentified four system engineering methods as practicable to be aware of for EPRS development specification and performance evaluation. These are the requirement analysis of functional specifications with regard to operational and performance requirements user receiver, the GPS and SBAS signal in space and models (i.e. measurement model, error models, error mitigation) that completely characterize systems, functional analysis that covers analysis of the allocation of functions to individual part of the system. The last is the test plan and criteria for evaluation of critical parts.

According to [3] requirements forms the key to understanding the significance and sensitivity of system functional specifications. When analysing system functionalities and operation we need to trace them back to their derivation from the system performance requirements.

SOFTWARE DESIGN

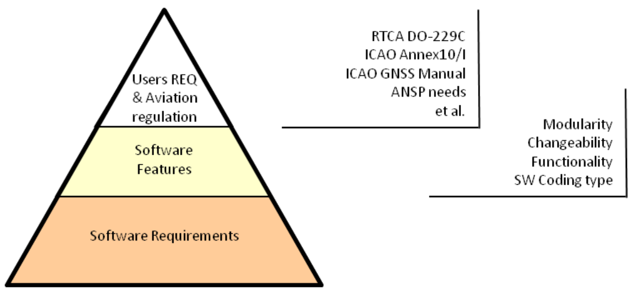

Figure 1 *–Software requirements derivation*

Software modules are well structured with an ordered hierarchy of blocks and modular subsections. It's well and easily applicable. Executable module programmed in C code, Convertor and GNSS measurement and correction preparation module, MATLAB code Core computation module. Author applied Tight Binding (all closely related items belongs same area) of modules and their Loose Coupling (minimized module contents interactions, other than direct sequence). Program is open to change which must be tracked to be corrected through the functional diagram. Functionality must be designed properly to not only fulfil previously mentioned requirements but also to prove all GNSS service assumptions that might influence aviation user supplied quality. It determines module configuration. Interface is dependent on multiple software utilization (C coded module, MATLAB, EUROCONTROL Pegasus). MATLAB is practical and in R&D usual tool for new function testing and development. Structured analysis and design software methodology has been therefore used. Software coding type C was used to create start EPRS-user interface, make initial settings and perform sequence of consecutive modules, see Figure 2. Only few selections are currently settled in the main function of MATLAB code. Every function of program is tested a unit and after that may be implemented to current EPRS version. Software testing starts with *Verification* (determining whether the software implements functionality and features) and is followed by *Validation (final EPRS user needs testing)*, i.e.determination whether or not performs the functions required to satisfy has been proceeded, black box testing [3].

SOFTWARE QUALITY METRICS DEFINITION

Quality is defined by ISO 9000 as: "*The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs*". [1] There are well know three classic software development models, McCall (consist of 11 factors, 1977), Deutsch and Willis (consist of 12 to 15 factors, 1988), Evans and Marciniak (1987). For the purpose of EPRS development Deutsch and Willis quality model is recommended to be utilized.

The different models did have one thing in common; each is based on the paradigm factor - criteria – metric. Each quality factor is composed of a number of criteria which in turn can be assessed according to anumber of defined Metrics.From Boehm et al McCall et al Bowen et al. Initially, there were defined following related quality terms: Adaptability, Reusability, Reliability, Expandability, Verifiability, Dependability, Interoperability, Accuracy, Integrity, Flexibility, Modularity, and Operability. In order to actually improve quality we need to connect quality factors to technical quality attributes of the product, i.e. low level attributes. Subsequently, quality metrics should be defined.

III. SOFTWARE TESTING

TEST PLANNING METHODOLOGY FOR SYSTEM

EPRS software forms part of the overall testing approach that has been designed. Usually test planning and preparation covers reviewing system requirements, test requirements and functional architecture. Designing and building test equipment and facilities and demonstrating end-to-end operation. GNSS testing covers the entire operation regime and comparing system performance with expectations, developing testing scenarios exercising system declared operating modes and measuring degree of compliance with all operational requirements and evaluating the readiness of the system for operation deployment.

APPLICABLE CONDITIONS OF OPERATIONAL TEST AND EVALUATION

EPRS software is part of complex process of system operational evaluation with feedback loop to functional deficiencies analysis, which usually part of ground SBAS system designer responsibility.

- Extensive preparation and local condition observation
- Test scenarios preparation for effective use of facilities and test results evaluation
- Clear and specific test procedures and detailed analysis plans should be done
- Fully instrumented test facility, op. environment
- Accurate data acquisition
- All system outputs should be converted into measurable quantities and recorded
- A sufficient number of test points should be monitored to enable tracing the cause of any deviation from test results. [3]

- Timely and accurate test reports.

IV. Software Architecture

Position accuracy, time series figures, satellite availability, Dilution of Precision (DOP) factors, accuracy (e.g. HPE, VPE, HNSE, VNSE, ellipse of concentration, ACF, PSD, worst ionosphere case NPA) and integrity performance figures (e.g. HPL, VPL, HMI, MI, URA), number of satellite vehicles (SVN) used, record of all received messages, identification of faults/failures and further functionalities, which description is beyond the scope of this article

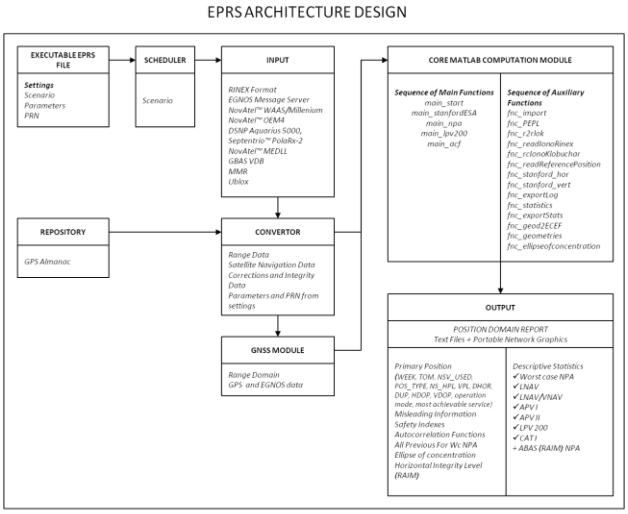

__Figure 2__ – EPRS Architecture Design

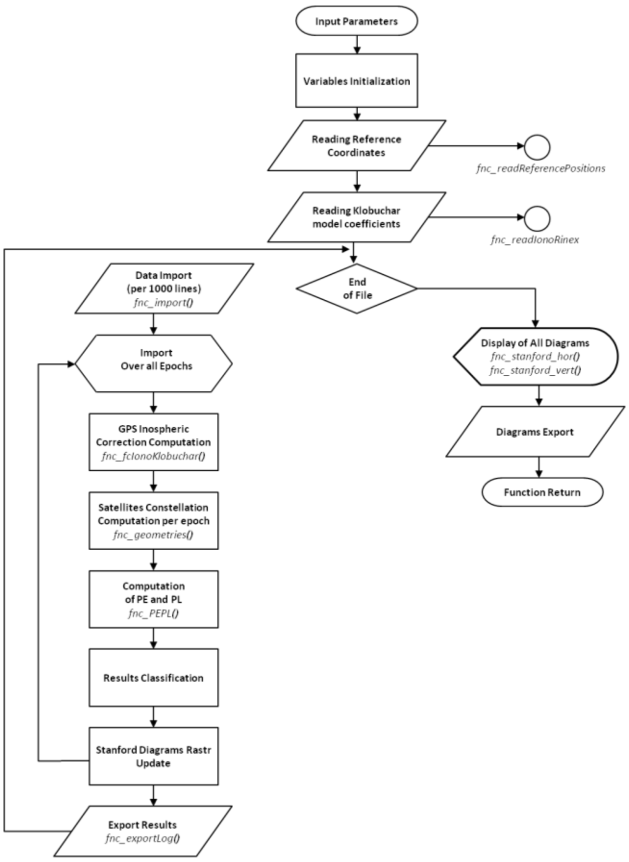

__Figure 3__ –Flowchart of the Main Algorithm

For any subject that will use the software or design new capabilities, functional system diagrams are designed, see example of the main EPRS algorithm flowchart on Figure 3. Modules are organized to enable multiple tasks to be completed, whether it is related to receiver simulation settings, range domain outputs or position domain output in report.

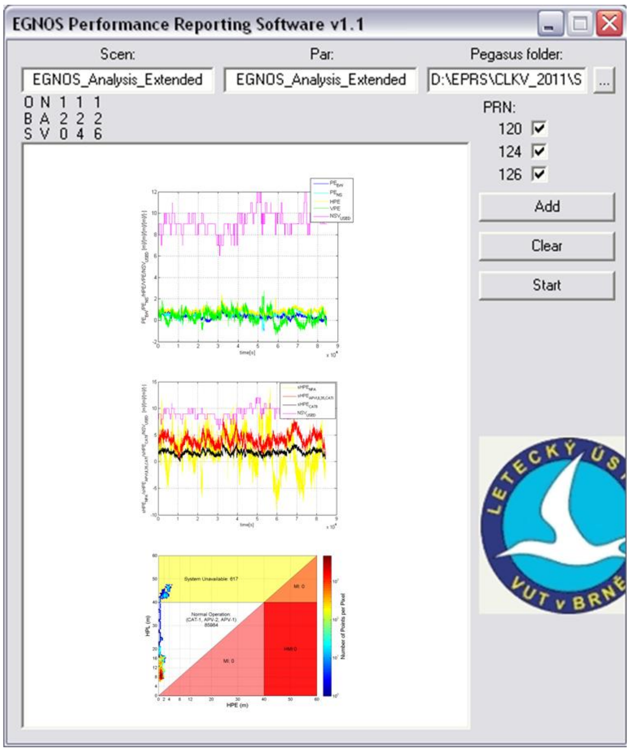

__Figure 4__ – EPRS Start Window

V. Conclusion

Contribution presents short introduction to procedures of EPRS software development and utilization for observed data evaluation from different station (covering all geographic region of FIR Praha) is ongoing software capabilities (see Figure 2). When finished, database of EGNOS characteristics with procedures for the assessment will become available.

VI. Acknowledgement

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POSSIBILITIES OF USING GNSS IN AIR NAVIGATION

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Abstract *– The issue of global navigation satellite systems (GNSS) is the number of potential uses in navigation and management of aircraft. The paper should be a description of the design possibilities replacement of approach navigation using conventional ground based GNSS systems especially at airports used mainly occasional commercial traffic and private businesses, the pros and cons of using these methods.*

Key words – GNSS, navigation, radionavigation, approach, RNAV

I. Introduction

Current satellite navigation system meant a qualitative leap in precision navigation, which reaches several meters, using special techniques differential is achieved accuracy within one meter. Thus arose the possibility of using GNSS for accurate navigation in the air and replace older ground-based systems.

Currently operating three satellite navigation systems, the American GPS and Russian GLONASS, European Galileo system, which can provide the basis for a new navigation system not only in aviation.

Article refers mainly to the use of a system of air navigation units mainly in phase approach to the runway. They are also described in the article specifically satellite systems and the possibility of their use. In article authors discussed detailed questions about systems like WAAS, GBAS, EGNOS, ABAS, GAGAN, MSAS, SBAS and GRAS, composition of their advantages and disadvantages, operations, differences and the identity of specific systems and equipment.

II. History of GNSS

Satellite-based radio positioning means in comparison with conventional methods radionavigation significant progress. Their main advantage is accuracy and allows you to work in a single coordinate system anywhere on earth. Despite the long-term development to a fully operational satellite-based radio navigation systems treated very cautiously and more recently, these systems have not been on in the wider professional community almost no information. At the beginning it should be pointed out that often come across the abbreviation GPS, which stands the English name of Global Positioning System (Global Positioning System). This shortcut is actually another name American NAVSTAR system. It is therefore not appropriate for use? GPS is not a common name for all satellite navigation systems. Currently becoming increasingly important two main satellite radio-navigation systems:

- American system NAVSTAR (Navigation Satellite Timing and Ranging)
- Russian system GLONASS (Globalnaja navigacionnaja sputnikovaja sistema).

The origin of satellite navigation systems to look for in 1957, when it was in the former Soviet Union launched into orbit the first artificial satellite. Extensive research in the field of navigation in this period took place in the USA as well as in the USSR (launched in the year 1967 the first Soviet satellite navigation called CYKLON). This foundation was laid construction of two famous satellite navigation systems.

In the first half of the 80th years, was built the American system NAVSTAR. [20]. For a breakthrough in the use of satellite navigation systems can be considered as the year 1983 when the U.S. decided to establish two subs under the NAVSTAR system. The first subsystem is the Standard Positioning Service (SPS), designed for casual navigation needs. This subsystem is characterized mainly by "faking" the error of determining the horizontal coordinates of about 100 ms probability 0.95. The second partition labeled Precise Positioning Service (PPS) is intended solely for the needs of the U.S. military and is much more accurate. [1] [5].

III. Available technologies in GNSS

The 21st century cannot even imagine the existence of civilization without the use of available satellite systems. The need to use them is palpable in many industries, in different modes, in governance, not least in geodesy. World powers to built for military and civilian use their own multilateral regional, global satellite systems and invest in their development of considerable funds. Systems that have been put into operation the first to continually review, refine and complement the new satellites. The current state of existence and operation of satellite systems is shown in the following table:

__Table 1__- types of navigation systems

Gen	name	country	status
Regional navigation systems			
	DORIS (Doppler Orbitography and Radio positioning Integrated by Satellite)	France	In use
	BEIDOU 1 (Beidou Satellite Navigation and Positioning System)	China	In use
	IRNSS (Indian Regional Navigational Satellite System)	India	In use
	QZSS (Quasi – Zenith Satellite System)	Japan	In use
GNSS			
GNSS 1	**GPS** (Global Positioning System)	USA	In use
	GLONASS (Global navigation Satellite System)	Russia	In use
GNSS 2	**GALILEO**	Europe	In preparation
	GPS	USA	In preparation
	COMPASS (BEIDOU 2)	China	In preparation
Augmentation satellite systems			
SBAS	**WAAS** (Wide Area Augmentation System)	North America, Hawaii	In use
	EGNOS (European Geostationary Navigation Overlay Service)	Europe, Asia	In use
	MSAS (Multi – Faction Transport Satellite Augmentation System)	Japan	In use
	GAGAN (GPS and Geostationary Augmented Navigation)	India	planned

GLOBAL NAVIGATION SYSTEMS

NAVSTAR (GPS)

The first navigation system called Transit launched the United States in the 60th Years. Was formed six satellites, obiehajúcimi the polar orbit of about 1075 km and three observation stations located in the United States. This system allows the use of Doppler observations to determine the relative position with an accuracy better than 1 m. The aim was to build a U.S. satellite system that would allow determining the location to the nearest mm. The final decision to build a new system for determining the position and exact time NAVSTAR GPS fell 17 decembra 1973rd Later the name was shortened to just GPS. First satellite of the system was launched in 1978, along with ten other is for testing and training system. In 1995 was completed operational phase system consisting of 24 satellites. It is stipulated that at any time and at any place be receiving signals from at least four satellites.

GPS was originally developed as a military system, but in 1981 was made available to a limited extent, to the public. In 1983 was used to solve the first geodetic problems. Selective aviability was restricted to the civilian sector, no 2 May 2005, however, this function has been canceled. Since then it is possible to fully use the GPS signal. The structure of the GPS consists of three main segments:

- Cosmic,
- Management,
- User.

Developed since the late 70 - ties of the former Soviet Union in response to the development of GPS. Today, development continues in the Russian Federation. For full and continuous operation of the system throughout the territory of the Russian Federation is required 18 satellites that operate in orbit for a long time. The other two satellites for the GLONASS system enabled the commissioning of the system for the provision of navigational signals worldwide, making it the second country the Russian Federation with its own satellite navigation system. Russian rocket Proton-M 14 December 2009 successfully earned the Baikonur cosmodrome orbital speed of three new navigation satellites Glonass-M. Thanks to the orbit is already 23 navigation satellites, of which 21 are fully functional. [15] By the end of 2010 was planned to place the orbital speed of the other seven satellites. Like the U.S. GPS is also GLONAS divided into space, control and user segments. A detailed description of each segment systems GLONASS, GPS, as well as newly constructed European GALILEO provides many authors in their publications and amount of information is available on the web portals.

GALILEO

GALILEO navigation system is built cosmic system, which should become an alternative to the U.S., the military controlled GPS system and the Russian GLONASS. Its construction is carried out by the European Union and other services would be provided by 2014. GALILEO will be completely independent of the other navigation systems, but when it will be compatible with them and the measurement will be able to use these systems. It will offer services intended for public use, especially for determining the position service for commercial use, with higher quality and accuracy services of life-saving services for government use - eg. for police, customs, in crisis situations, the search and rescue use.

The system should consist of 27 operational and three backup satellites orbiting of 23,616 km above the Earth's surface along a path inclined 56 ° to the Earth's equator, in three dimensions against each other shifted by 60 ° (nodal lines). The other three satellites, one in each plane will form a backup operation in orbit, the system can be in technical failure of any satellite immediately by the full number.

COMPASS

China as the next superpower unveiled the latest plans for building your own global navigation satellite system (GNSS), which is the forerunner of a regional system Beidou 1 When finished, the Chinese Beidou 2 system (COMPASS) becomes the fourth global satellite navigation system, independent from the American GPS, the Russian GLONASS and European Galileo, allowing Chinese civilian and military sector use its own technology. The first satellite of this system was to track geostationary earth placed in October 2000 in order to mark the third satellite Compass-G1, also known as Beidou-2 G1, was the orbital speed of the Earth successfully placed 17 January 2010. China plans in the future to delete the orbital path for global coverage of the Earth five geostationary and non-geostationary satellites 30. By unveiling plans initial phase of COMPASS will cover the Asia-Pacific region with navigation services, a synchronization (timing) services and communication services, using short messages. The current plan says the global coverage by 2020. In the table are mutually compared existing and building, building satellite systems.

IV. USE OF GNSS IN AVIATION OPERATIONS, ESPECIALLY IN THE APPROACH PHASE

In civil aviation, the use of satellite navigation almost standard for granted. In this period, the use of this type of navigation is available only in American (military) GPS system, or its advanced systems. Given that, for use in the civilian GPS service is some way of deficiencies is to integrate it with other presently used navigation devices and systems.

It will soon be upgraded first GPS itself, both Russian (also military) global navigation satellite system Glonass (both in about the year 2010) and will complete construction of civil satellite navigation system Galileo (also in r., 2010). The three systems and extended systems (GPS-based) are abbreviated GNSS (Global Navigation Satellite Systems).

ICAO (International Civil Aviation Organisation) foresees the use of GNSS as sole (sole means) means for all phases of flight. Of course, by then it will be necessary to ensure that GNSS meet all operational and safety requirements. Satellite navigation should constitute a major innovative trend in aviation in the near future. To be fair to the period when they GNSS navigation system is certified as a Class sole means. When you use the GPS it is not yet possible because of a lack of continuity. Continuity ensures that the system will be operational during the entire operation. The second reason is the lack of positional accuracy, which should provide the ability to observe the degree of accuracy with 95%. The last parameter is availability, which requires hedged fitness of the system, operationally identical to the one now being achieved in other navigational equipment and systems. [5]

GPS is technically limited in parameters such as accuracy, availability and integrity services. Constellation of satellites does not guarantee a sufficient number of satellites visible above the horizon observer is therefore not reliable enough for all phases of aircraft on landing approach, which necessitates the need to use other systems. Guaranteeing the availability of the Ministry of Defence of the United States is insufficient to convince users to abandon existing systems. In addition, we must recognize danger of a single system in this phase of flight, consisting of defencelessness against illegal acts, and so on.

ICAO is naturally cautious with the introduction of the necessary skilled procedures. In addition, professionals as a whole are naturally conservative their activities require large investments, especially for ground equipment and aircraft instrumentation. In terms of a vision for the next 15-20 years is predicted (compared to now) the simplification of equipment cabin, saving the cost of maintaining and building expensive diverse terrestrial navigation infrastructure. This vision will encourage industry to adopt the concept of satellite navigation. To the ICAO embraced this concept is essential to navigation satellite system was controlled by civil authorities to guarantee constant availability.

Galileo occupies this unique strategic position, will be fully interoperable with the other GNSS in all aircraft applications. The existence of another cosmic segment, controlled civilian authority ensures all requirements for availability, integrity, accuracy and security of the system. We discussed of the various stages of flight in terms of these parameters. Approach is one of the most sensitive maneuvers conducted pilots, especially in adverse weather conditions. Should we have yet to realize that in the long term is to be implemented full automation of the aircraft and air traffic management services, in the period 2020 – 2030. Remains to be done a lot of work, but the European system Galileo may represent a major step towards achieving this.

V. CONCLUSION

The basic aim of research is to be proposing procedures for approach and landing aircraft using global satellite navigation systems for selected airports in Slovakia. While the secondary objective of the research is the analysis advanced satellite navigation systems and analyze the cost of implementing satellite navigation, together with an assessment of the advantages and disadvantages for specific airports.

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INFLUENCE OF THE FATIGUE ON THE TWO-MAN FLIGHT CREW PERFORMANCE

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Abstract *– The paper deals with the issue of the research on the fatigueeffect on the flight crew performance. One of the ways to carry out such research within the technical university is to use of available technical (flight simulator) and human (pilot student) sources. The purpose of this paper is to show the results of one of experiments using the example of curves showing the dependence of fatigue symptoms and errors on the experiment time run.*

Key words – Flight crew performance, fatigue, mistakes, flight simulator

I. INTRODUCTION

The main objective of the airlines is to carry a maximum number of passengers and their needs for the target destination. This, of course, with the highest profit, the safety is generally maintained at a minimum level of aviation regulations. Operators are trying to increase profits and reduce costs, and it would ideally need to have their planes constantly in operation and minimize the time spent on the ground. For this scenario, they need greater number of pilots, or their greater workload.

Without adequate rest there may appear a fatigue which influences the functioning of the human body. An accident investigation revealed that 70% of all aviation incidents and accidents resulting from a human error, where 15-20% of accidents were caused by the crewfatigue [4]. In 2012, the European Pilots Association conducted a study which found that one third of European pilots already once fell asleep in flight. A third of them admitted that on waking found that the second pilot was asleep too. Also research of the Portuguese Institute of Civil Aviation (INAC) concluded that the flight crew is very often too tired.

To prevent errors is always cheaper and safer than to learn from their results. For prevention there is possible to use different models, complex systems or simulation. The purpose of this paper is to present one of the experiments which use a flight simulator to determine the dependence of the flight crew to its level of fatigue during simulated flights.

II. FLIGHT CREW PERFORMANCE IN TERMS OF CREW FATIGUE

There are many types of flights, which are divided into different categories. One possible division of flights is the duration of the flight including the briefing end debriefing time. After a rest or sleep, the body is able to function again until it exhausts energy, which must be regenerated. The time between relaxations can be called flight crew endurance. It is the ability to maintain performance within safe limits when performing physical and mental activities, and each individual is different this time. There are many factors that can affect the crew endurance. They can be divided into four basic groups:

- Factors associated with physiology and psychology (mental and physical condition)
- Factors related to lifestyle (quality of sleep, food, drinks)
- Factors associated with the environment (temperature, humidity, noise ...)
- Factors associated with long-term workload (accumulated fatigue)

III. EXPERIMENT CONCERNING THE IMPACT OF THE FATIGUE ON THE FLIGHT CREW PERFORMANCE

There are various mechanisms to predict the technology and human behaviour, from a theoretical research to a practical experiments and simulations. In all sectors of the aviation industry operates a large number of scientists who in the framework of cost try to verify the theoretical limits in which the safe operation of aircrafts is still possible.

Unlike technology is human being receptive, and it is therefore necessary to examine also his psychological traits, where every individual is different. Each human is defined by his attitude, personality profile, patterns of behaviour, psychological conditions, etc. There are studies of human behaviour in specific situations, and descriptions of behaviours that are based on long-term observations of a large number of individuals, but cannot yet say exactly how a particular person will in particular situation behave.

Preparation of the technology

The central technological element of the whole experiment, besides the crew, is the appropriate flight simulator which had to meet the following parameters:

- sufficiently faithfully imitation of the two-man flight crew work environment
- by means of using audio - visual system faithfully imitation the real flight illusion
- flight crew separation from other experiment infrastructure
- to include the technology required to record data (time, video and voice recording system, instructor workplace display recording system, etc.)

With regard to the costs and the simulator function for the purpose of this kind of experiment seemed to be sufficient uncertified FNPT flight simulator used at the Air Transport Department. Using panoramic view from the cockpit and faithful simulation apparatus together with simulating ATC communications can make sufficiently realistic flight environment.

Preparation of the human resources

For a successful experiment performance is necessary the preparation of the human resources like the flight crews and the experiment supervisor. The overall flight crew and supervisor readiness for this experiment consists, inter alia, from

- the supervisor readiness to control the technology used to efficiently record and evaluate the tiredness and mistakes
- the flight crew and supervisor readiness of the tasks during the experiment, ie., that both pilots and supervisor must have sufficient experience
  - with the flying on the type of flight simulator
  - with flying under SOP used in commercial air transport
  - with flying in multi-member crew (MCC)
- the flight crew readiness to the experiment, so that at the beginning showed symptoms cumulative fatigue (disturbed circadian rhythms of past days) to allow during the time-limited experiment to achieve sufficient tiredness

Data recording system

Based on the technical possibilities the following sample data will be recorded during the experiment:

- Unified time during the experiment
- CCTV data in major intervals
- Continuous instructor workplace screen data
- Communication data
- Subjective fatigue of flight crew members at certain intervals of the experiment
- Deviations from standards data recorded by the experiment supervisor
- Flight crew fatigue symptoms recorded by the experiment supervisor

An important requirement was the unified time of the experiment, with which the individual records can be synchronized for later experiment evaluation.

Deviation assessment

Evaluation of errors due to fatigue had to be designed to the experiment possibilities; it was based on the errors frequency and severity along the experiment unified time. Errors were determined as any deviation from the standards that the flight crew must comply with during the flight,there have been following standards established:

- Flight procedures (AFM - Aircraft Flight Manual)
- Standard operating procedures (SOP)
- Checklists (C / L)
- Route and airport´s charts

The error´s frequency was determined so that the experiment supervisor continuously recorded subjectively observed deviation from the standards (which in some cases were objectively recorded by the instructor station). The error´s severity was established so that to each error (deviation from standard) was by the supervisor subjectively assigned threatened species according to the kind of the severity (incident, serious incident, accident)

Experiment execution

To ensure the highest possible level of credibility was to create the most realistic scenario, the experiment consisted of the following parts:

- Preparation of techniques including
  - Ensuring of proper operation of the simulator
  - Provision and installation of recording technology
  - Creation of a working environment for the experiment supervisor
- Ensuring the persons conducting the experiment, including
  - Flight crew selection
  - Ensuring their readiness for the experiment demands
- Design of experiment scenarios, including
  - Preparation of documentation
  - Scheduling of flight scenarios
- Recording the experiment results, including
  - Observations during the experiment
  - Recording data from the measuring and recording devices
  - Recording of standards deviations

Experiment results

The experimental results are primarily the evaluated data from recorded equipment transferred to graphs that show the cumulative flight crew fatigue,flight crew errors frequency and severityand its competent timing of.

The fatigue symptoms appearance in time

The graph below shows the timing and number of individual members fatigue symptoms of recorded by supervisor´s subjective analysis of their face's video recording.

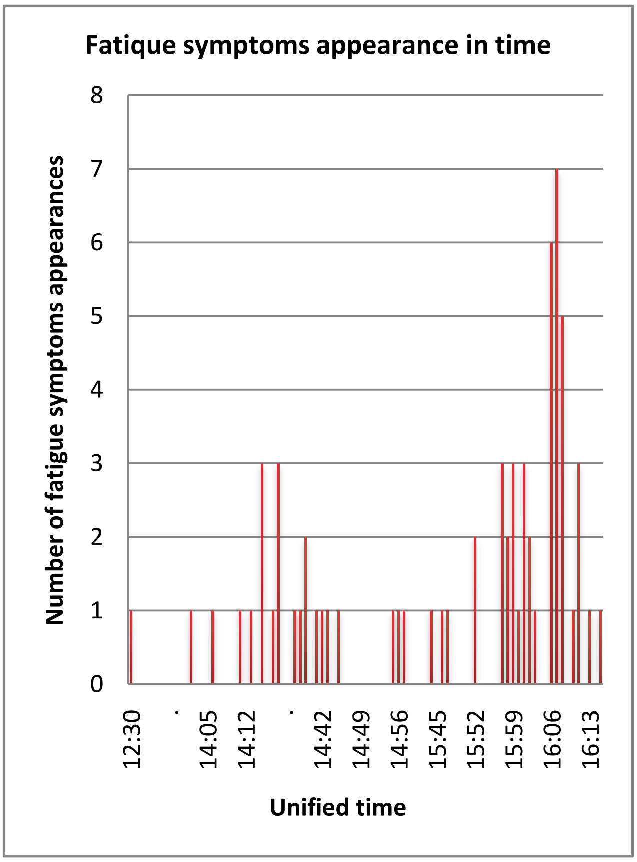

***Figure 1** – The appearance of the fatigue symptoms in time*

Subjective fatigue ratings using flight crew questionnaires

The graph below shows the results of a subjective evaluation of the flight crew fatigue status in the course of the experiment based on the questionnaires completed for the various stages of experiment.

Deviations incidence and severity in time

The graph below shows the errors timing and severity by individual crew members recorded by the supervisor due to subjective analysis of the cab simulator overall view record, the communication record or instructor workplace data records.

IV. Conclusion

The basic aim of the experiment was to show the influence of the fatigue on the flight crew performance described by the available technical and human resources to the students of the appropriate study branch. Participating students had the opportunity to learn first-hand the effects of the fatigue on their performance and to compare their subjective perception of the situation with more objective record of reality. The experiment provided valuable data that will be used in planning further experiments on the topic.

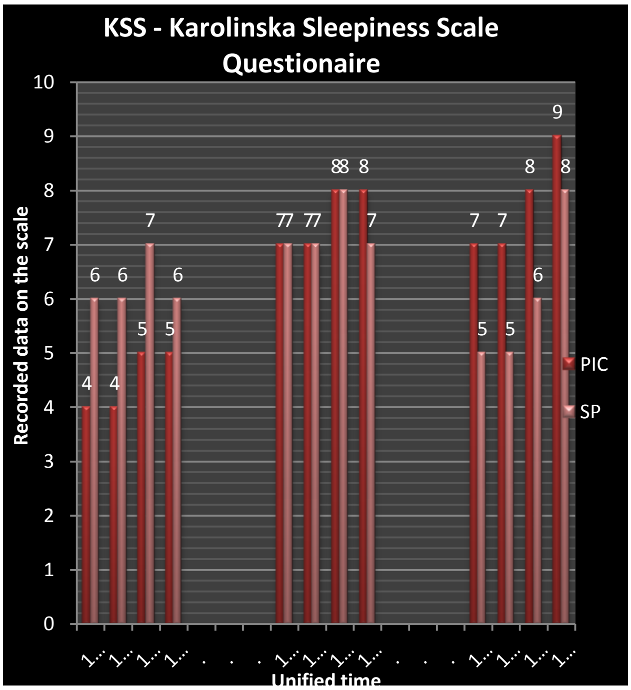

***Figure 2** – Subjective fatigue ratings using flight crew questionnaires*

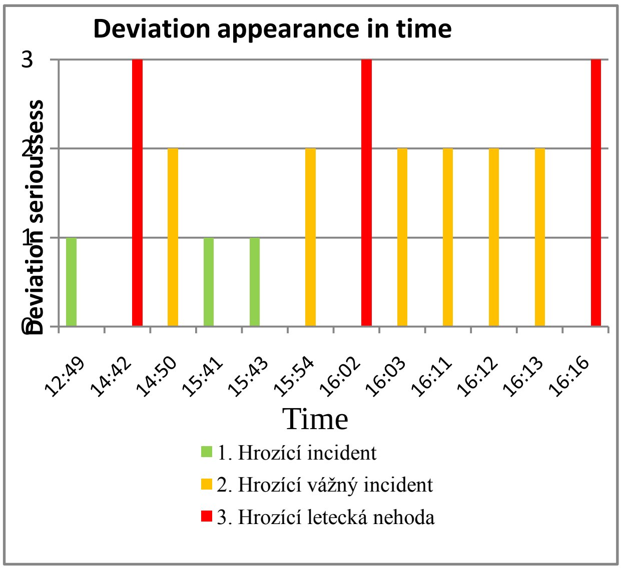

***Figure 3** – Deviations incidence and severity in time*

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FEM APPROACH TO ESTIMATE LARGE DEFORMATIONS OF STIFFENED FUSELAGE STRUCTURE

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Abstract – *During participation in a project called MOSTA that is held by Aircraft Industries, a.s. a FE models of the rear fuselage structure of L 410 UVP-E and L 410 NG (New Generation) were created. Non-linear analyses of the models by means of the SOL106 and SOL600 non-linear solvers of MSC.Nastran and MSC.Marc were performed. Also the analytical analyses of two L 410 UVP-E fuselage critical sections were made for comparisons. These two types of analyses were made with the aim to evaluate progress of stiffness changes andfailures of the structure. Finally the comparison of the results of FEA and analytical analyses with the results of the static strength tests ofL 410 UVP-E is presented and discussed.*

Key words – thin-walled stiffened structure, aircraft fuselage, non-linear analysis, FEM, FEA, local and global buckling.

I. INTRODUCTION

The local stability problems for metal thin-walled stiffened structures are well investigated. There exist methods for analytical evaluation of critical forces, critical stresses (strains) and deflections of skin and stringers.

But if we are talking about global stability of the structure there exist just approximate methods that are quite complex, time consuming and do not give satisfactory results. Therefore engineering society is looking for other means that could help in this problem. One of them is non-linear FEA.

Nowadays FEA software market offers a row of quite powerful and flexible non-linear solvers that can be used for a wide range of non-linear problems solving. The MSC Company has several their own non-linear solvers imbedded in MSC.Nastran and MSC.Marc software. SOL106 and SOL600 are among them. These solvers provide several solving algorithms, methods and features that have a row of customization parameters. The parameters help to customize the solvers' tolerances and also help the solution to converge successfully. The results of the solutions are very sensitive on changing these parameters. Moreover, the results accuracy depends on the solver type.

During MOSTA project held by Aircraft Industries a.s. it was decided to use MSC software for non-linear analysis of the L 410 NG rear fuselage in order to predict local and global buckling capacities of the structure. Before this the Aircraft Industries, a.s. required to know the accuracy of this software. Therefore the rear fuselage FE model of previous modification of the airplane L 410 UVP-E was created, loaded with one of the critical load cases and analysed by means of SOL106 and SOL600 non-linear solvers. After that the results of simulations were compared with results obtained from analytical calculations and static strength tests.

II. SOL106 AND SOL600 SIMULATIONS

The most of the rear fuselage structure was modelled by shell elements. The stringer flanges attached to the skin were modelled integrally with skin by the same shell elements. The stringer webs and flanges were modelled by one element along their height.

The analysis of the rear fuselage structure was computed with large deformations due to the structure dimensions. This geometrical non-linearity influences the convergence and cause increase of time consumption. Other materials non-linear behaviour and contact options were not used.

For SOL106 simulations the difficulties with convergence occurred. The solution either diverged or began stagnating at the load levels close to beginning of large structure deformations. Therefore several solving methods of NLPARM data entry were tried [1]. They were default AUTO method, ITER, SEMI and PFNT [1]. The most successful was ITER method that helped to obtain converged solution. The other important parameters of NLPARM data entry were tolerances EPSU, EPSP, EPSW and test parameter CONV those directly influenced the convergence. They were adjusted during trial simulations.

Simulations with SOL600 appeared to be simpler in terms of adjusting. As sufficient settings the default parameters except Maxtimestepwere used. This parameter was set to 0.01 in order to obtain more accurate output data, especially at load range corresponding to buckling and postbuckling processes. The simulation output data were drawn and compared in relations displacements/stresses/strains to load/time where the strain/stress - load/time curves had very complex shapes.

At first approach the displacement fringes, which vary at each load step helped to indicate the starting moment of skin local buckling and its progress during the increase of load. The displacement fringes with buckled skin obtained from SOL106 and SOL600 results are shown on Fig. 1. As can be seen from the figure the solvers give similar results.

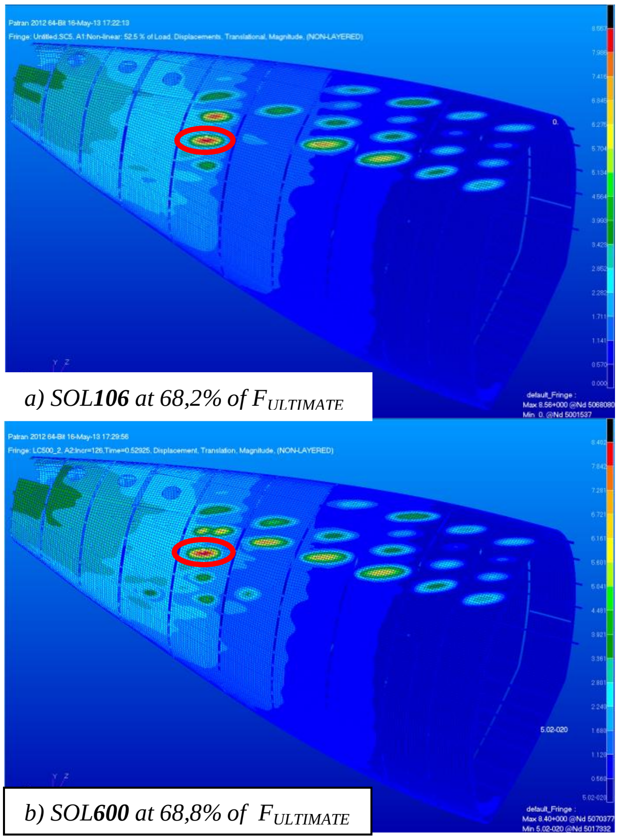

***Figure 1** – Displacement fringes with buckled skin*

The progress of changes of skin waving, losses of stability and stiffness were evaluated in several typical graphs. The most useful were displacement-load and strain-load relations. Also the Internal force-displacement relation showed development of skin buckling.

For more accurate definition of critical loads for skin and stringers the strain-load curves can be used. These curves for critical region 13 (highlighted with red ellipse on fig. 1) are shown on Fig. 2. The curves are drawn for upper and lower surfaces of the skin at different points. The starting moment of skin local buckling occurs when one of the curves shows first local minimum. It means that one of the skin surfaces quickly begins to elongate after contraction that corresponds to skin local bending and buckling. In the case shown on fig. 2 it happened at 64% of ultimate load.

Curves for one of the adjacent stringers at the middle of the bay are shown on fig. 3. Different curves correspond to the surface of the flange adjacent to skin, outer point of the web and COG of the stringer. The column buckling of the stringer can be indicated by prompt and significant slope change of the curves corresponding to its most outer points. At the same time one of the curves should show tension and another compression. That means significant bending of the stringer as a result of buckling on fig. 3.

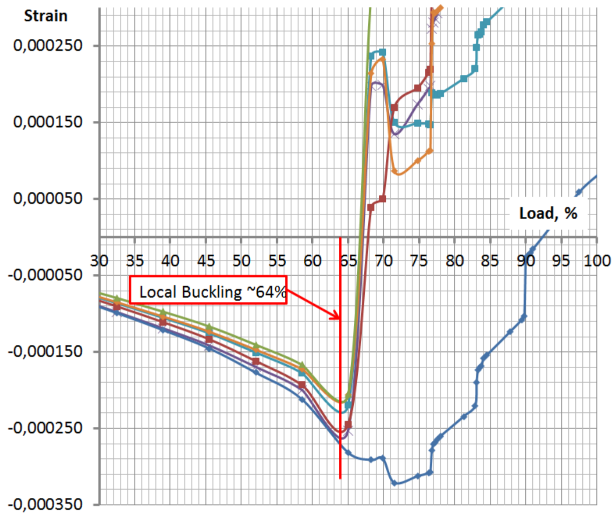

***Figure 2** – Strain-load curves for skin from SOL106 results*

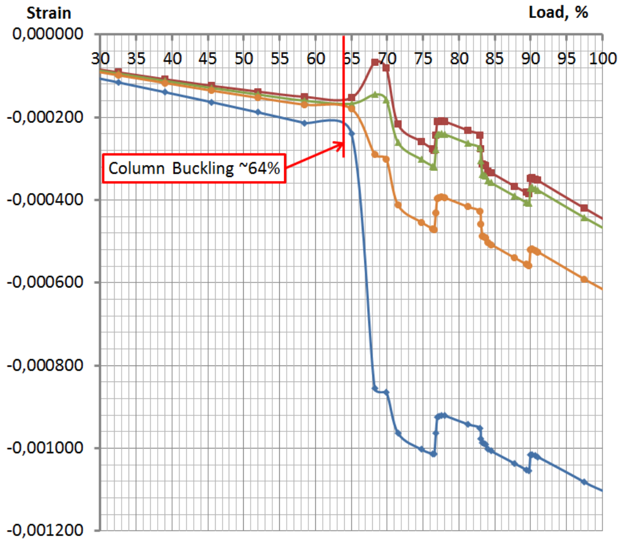

***Figure 3** – Strain-load curves for stringer from SOL106 results*

III. ANALYTICAL ANALYSIS

The analytical stress analysis in selected sections of the rear part of the fuselage was made in the STAUNO software, where a progress of skin failures, stringer failures and the global load capacity of a structural section were determined. This software is based on the previous software, made by authors Ing. Píštěk and Ing. Grégr, where the Gradually increased load method is used. With this software a resultant impact of applied load could be derived for the simultaneous combination of load components, not only for separated particular load components. The main advantages of this analytical analysis are prompt evaluation and effortless modifications.

In this analytical analysis the development of skin failures was observed. At each step the load is gradually increased and a new weakest structural element and its properties are derived. The part of results from the output file is shown in the Table 1, where the number of step, region with failure, stresses and finally the load coefficients are listed.

Table 1 – *Example of output result table from analytical analysis*

Step	Skin region	τ [MPa]	σ [MPa]	Load coef.
3	13	-15,0	-2,7	0,558
4	25	-11,3	-13,3	0,582
5	23	-18,9	-7,1	0,663

The load coefficient is a ratio of the critical skin failure load to the global ultimate applied load. Thus for the moment of a skin region failure due to critical shear or normal stresses the portion of load is evaluated.

IV. Results comparison and discussion

The rear fuselage structure of L 410 UVP-E was subjected to static strength tests during its development stage [2]. And there is an effort to simulate the similar behaviour of the skin buckling for the identical conditions and the load case LC 500 (gust on vertical tail unit).

Progress of the skin failure could be derived from graph on the fig. 2, where after constant slope of the curve, the initial waving of the skin started and while bending is increasing the skin stress reach the critical value of the local buckling stress. An exampleofthe skin bucklingin the real structure during static strength tests is shown on the fig. 4. Significant deformations and buckled regions are marked by red arrows.

Some regions correspond to the static strength test results but some regions lose their stability earlier on SST than in FE analysis. It is quite difficult to determine the moment of skin buckling from the complex shape of the particular curves. And also the earlier skin waving on SST is caused by influence of changes in surroundings. Therefore additional strain-load curves obtained from FEA results were analysed for 31 critical regions of the structure. The minimum load carrying capacity of the skin is 64% of ultimate loadat region situated in upper portion of the rear fuselage.

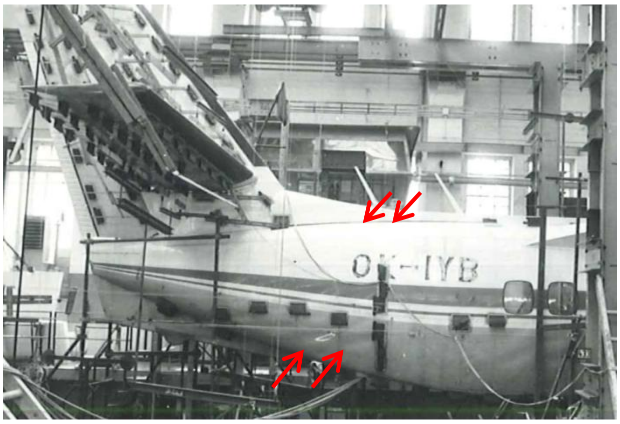

Figure 4 – *Initial deformations of the rear fuselage skin at 50% of ultimate load*

The analytical method in comparison with static strength test results gives higher values of the skin buckling load. It is caused bynot taking into account the geometrical non-linearityin this particular method. The structural elements are assumed to stay in their original positions without displacements and changes of their geometrical shape. After an element failure only the reduction of its particular characteristics is made. The accuracy of the theoretical computation could be verified by comparisons with the SST results for an each skin region.

The lowest value of the skin failure load could be determined by the static strength test, due to an effect of a real interaction among the adjacent elements, geometrical non-linearity, real imperfections of structural elements shape and material properties.

V. Conclusion

According to the performed investigations the non-linear FE analysis with geometrical non-linearity of a complex thin-walled structure could be used for critical regions localization and prediction of the critical local buckling load of the skin. But an additional research is required with possible improvements of the FEM and alsodeeper comparison with static strength tests should be done.

Acknowledgment

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This project was realized with financial support from national budget of Ministry of industry and trade of Czech Republic.

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A VISION OF THE FUTURE AEROSPACE

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Abstract *– The paper is focused on the quite new ICAO's approach to Air Traffic Management. The aim of this paper is to introduce the Aviation System Block Upgrades as an inherent part of the future aerospace. It provides a basis for further analysis of individual modulestheir and resemblance with NextGen and SESAR — the key players in delivery of a coherent, performance-based global air navigation system to achieve an International Civil Aviation Organization's One Sky vision.*

Key words – Aviation System Block Upgrades, ASBU, ICAO, GANIS, GANP.

I. INTRODUCTION

Air traffic growth expands two-.fold once 15 years but it could be "double edge sword" and the stakes are high. The challenge is how to achieve both safety and operational improvements which are environmentally responsible and cost-effective. The increasing pressure on infrastructure and facilities which are already stretched to the limit in many parts of the world and the potential lack of global harmonization will restrict air transportation if we continue along the same path. As a result, the future ATM programmes simply have to work and must be interoperable. International Civil Aviation Organization has adopted the name *One Sky* for its vision to achieve a harmonized global air navigation system. The One Sky approach is intended to be progressive, cost-effective and co-operative. The approach consists of three levels of activity: global conception, regional implementation planning and national implementation of infrastructure. At the heart of the One Sky approach is the "Block Upgrades" architecture – the framework to deliver a global interoperability.

These issues were first-time introduced to the international community at the *Global Air Navigation Industry Symposium* in 2011. The meeting recalled the Global Air Traffic Management (ATM) Operational Concept contained in *Doc. 9854*. Consequently, ICAO organized the 12th Air Navigation Conference in Montréal, from 19 to 30 November 2012 with participation of its Member States and invited international organizations. The main topic of the conference were block upgrades which comprise various operational improvements aimed at harmonizing and improving the efficiency of the Global Air Navigation System. To aid in the harmonization the block upgrades were supported by a roadmaps for communications, navigation and surveillance as well as an information management and avionics.

II. AVIATION SYSTEM BLOCK UPGRADES

The Aviation System Block Upgrades (ASBU) is a methodology to implement the ATM system based on operational concepts extracted from the NextGen (USA), SESAR (Europe) and CARATS (Japan).

It designates a set of improvements that can be implemented globally from a defined point in time to enhance the performance of the Air Traffic Management system. Each module is a deployable package (performance) or capability. A module will offer an understandable performance benefit related to a change in operations, which is supported by procedures, technology, regulation/standards, as necessary, and a business case. A module will also be characterized by the operating environment within which it may be applied. In turn, a block is made up of modules that, when combined, enable significant improvements and provide access to benefits. The whole framework consist from 47 modules which are positioned into a matrix. (Fig.1)

The ASBU Matrix:

- Block (horizontals)
- Performance Improvement Areas (verticals)

A block is made up of several modules. A combination of Modules within a Block represents a fully functional and cohesive ATM system at a certain point in time – in this case, over 5-yearly increments. There are four 'Vertical' components grouped together to represent a cohesive and functional end-to-end ATM system. These 'verticals' are also individually characterized as Performance Improvement Areas which can be base-lined on a global basis as a mature and available performance improvement, supported by the requisite ICAO Provisions and Standards for implementation worldwide. [2]

PERFORMANCE IMPROVEMENT AREAS

1. Greener Airports
2. Globally Interoperable Systems and Data through Globally Interoperable SWIM
3. Optimum Capacity and Flexible Flights through Global Collaborative ATM
4. Efficient Flight Path through Trajectory Based Operations

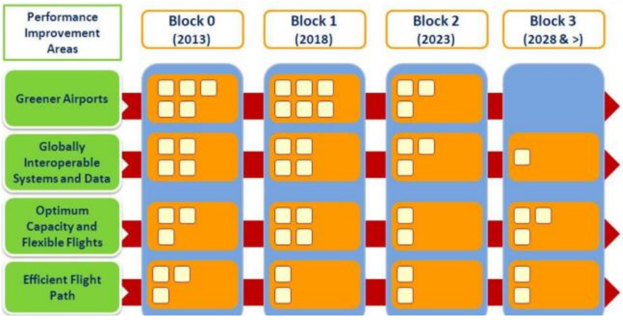

Figure 1 *– Summary of Blocks Mapped to Performance Improvement Areas [1]*

Each Performance Improvement Area has 4 Blocks (Blocks 0, 1, 2 and 3). Each block has a number of corresponding modules described in standardized templates.Timing of blocks is following while theBlock "0" optimizes current onboard equipage and provides baseline.

- Block 0 –Baseline (15 modules): 2013
- Block 1 (16 modules): from 2018
- Block 2 (10 modules): from 2023
- Block 3 (6 modules): from 2028/beyond

Objective

Key to the achievement of a globally interoperable ATM system is a clear statement of the expectations/benefits to the ATM community. The benefits are referred to eleven Key Performance Areas (KPAs) and are interrelated and cannot be considered in isolation since all are necessary for the achievement of the objectives established for the system as a whole. It should be noted that while safety is the highest priority. The eleven KPAs are shown in Table 1.

Table 1 *– ASBU – Key Performance Areas*

access & equity	**environment**	**safety**
capacity	**flexibility**	**security**
cost effectiveness	**global interoperability**	**participation of ATM community**
efficiency	**predictability**	

However, out of these eleven KPAs, for the present, only five have been selected for reporting through ASBU, which are **Access & Equity, Capacity, Efficiency, Environment** and **Safety**. On this basis has been prepared a framework which contains roadmaps for the essential operational and technological changes required from all stakeholders to achieve the performance objectives set by the ICAO's *Global Air Navigation Plan (GANP).* The GANP is a strategic document that has successfully guided the efforts of States, planning and implementation regional groups and international organizations in enhancing the efficiency of air navigation systems. It contains guidance for systems improvements in the near/medium-term to support a uniform transition to the global ATM system envisioned in the Global ATM Operational Concept.

It provides the basis for the timely, coordinated and efficient deployment of new technologies and procedures, whilst ensuring alignment with ICAO's Aviation System Block Upgrades (ASBU) for global interoperability and synchronisation.

III. Discussions

Harmonization is easy to talk about, and very difficult to do. All is about right planning and precise timing. Harmonization is most effective after concepts are fairly mature, but before significant funds are expended on particular solutions. So, the time is right.But this industry some time has suffered from the "chicken and the egg" problem. In order to move forward, the Airlines need to know that they will receive the benefits promised, so do the Air Navigation Service providers. And the equipment manufacturers need to know what systems to build. The investment decisions to the aviation system will need to be synchronised so that all elements of those Systems invest at the appropriate time to enable ultimately delivery of the operational benefit. And in addition, we need to concentrate on how we will certify these new systems and procedures much earlier in the process. Any why plan that way?

This is the reality of our aviation system today. Different States are launching different initiatives in order to accommodate their expected traffic growth.

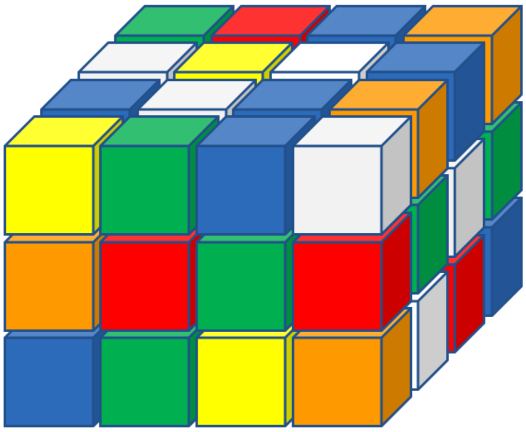

Figure 2 *– Illustration of our aviation system today [3]*

However, in order to achieve a globally harmonized system, we need to have those States, and all other stakeholders, come together and agree of what elements of those systems need to be harmonized, and what elements of those systems need to be interoperable. Other questions unanswered are:

What key decisions will we, as an aviation community, need to make to have seamless operations? And how can the industry assist in those decisions?

We know that the benefits of this system are obvious. So let's talk about potential risks, challenges and next steps. All plans face risks and require appropriate approach. The most significant risk in global airspace modernisation is related to timing and the mix of technical, political, and infrastructure requirements. As the airspace is intended to a State's unique needs and a business case, there are risks that exist independent of the specific solution.

These include:

- Non-homogeneous deployment across the regions

- Lack of synchronisation of air and ground deployments
- Future investment in the existing ATM programmes by key stakeholders not secured
- Delays in standards development and approvals
- AIM not implemented in a global interoperable way
- SWIM not implemented in correct form.

The deployment of block upgrade is seen to resolve many of these identified risks. The timing and sizing of these upgrades are in response to the need for mature standards, integrated air and ground solutions, and the establishment of positive business cases that bring identifiable benefits forward for a level of equipage and infrastructure cost. Those capabilities that lack specific maturity in content or described benefit are purposefully placed in the later block upgrades.

Block upgrades also respond to the issue of "non-homogeneous deployment across regions". Each block and its underlying components are intended to interoperate seamlessly and independently of how they are implemented in neighbouring States. This ensures that procedures, training, policy, and other "infrastructure" are consistent, enabling a safe transition to a more capable airspace.

Block upgrades were defined to minimise their specific risks but, it is not possible to foresee all potential issues associated with timing and adoption. In that regard, block upgrades bring the following risks:

- States may not be capable of ensuring successful deployment of Block 0
- If Block 0 is not implemented as a foundation, certain functionalities may not be available as enablers for future blocks
- Identification and resolution of policies necessary to enable the future blocks
- Delays in availability of new technologies to support implementation of Blocks 1, 2 and 3
- Delays in availability of SARPs
- National regulatory frameworks may be unable to support implementation of Blocks 1, 2, and 3. [4]

However, having established a structured roadmap, stakeholders now benefit from a framework for discussion and resolution of open issues associated with the specific risks attributed to the block upgrades. The mapping provided by the block upgrades gives ICAO and industrial standards makers a tool to unify and synchronise action in a coherent manner. This is expected to limit the scope and complexity of the challenge towards achieving global airspace modernisation. For the standards makers this provides a basis to coordinate efforts, avoid duplication, and deliver global and interoperable, unified standards. Various actors of industrial standardisation should combine their efforts to support those of ICAO as well as in delivering the proper framework to the Industry to develop and implement the relevant technology.

IV. Conclusion

Over the past ten years, as the ATM operational concepts were developed, the need was recognized to integrate the air, ground and regulatory parts of aviation including airport operations, by addressing flight trajectories as a whole and sharing accurate information across the ATM system, distribute the decision-making process, address safety risks, and change the role of the human being using improved integrated automation.

The global aviation system block upgrade initiative constitutes a worldwide framework for ATM system modernization. Offering a structure based on expected operational benefits, it will facilitate investment and implementation processes, by clarifying the clear relationship between technology and operational improvements. ASBU is a method to achieve standardisation of ATM performance worldwide to ensure that all systems are compatible with each other, and that all aircraft have been modernised. It is expected that to achieve this standardisation of the world's air transportation system will cost $120 billion over the next ten years.There will be many challenges to manage, not least the political and economic turbulence of the 21st century, but firm foundations are being put in place for a global airspace which is fit for the future.

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SAFETY ASPECT OF ELECTRIC POWERED AIRPLANE

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Abstract *- This paper deals with safetyaspects of electrically powered aircraft. Environmental issues have rising importance in aviation and electrically powered airplanes are environmentally friendly alternative aircraft powered by conventional internal combustion engine. A newmethod of propulsion brings also new risks associated with the onboard electricity storage system. The paper compares safety aspect associated with electric propulsion based on batteries and hydrogen fuel cells as major energy source for propulsion of the light sport aircraft. The paper presents activities done also an experimental electrically powered aircraft VUT 051 RAY, which is developed by Brno University of Technology with contribution of JIHLAVAN Airplanes Company.*

Key words – safety, electric, battery, fuel cell, VUT 051 RAY.

I. INTRODUCTION

In the growing need for more environmentally friendly and efficient travel, researchers, technologists, and inventors are pushing the limits of our current technology. Environmental taxes and laws restricting emissions and pollution are beginning to drive the design of our future transportation vehicles. Powering an aircraft with an electrical power system is not new. Several attempts were made in the early days of aviation to incorporate electrical power into aircraft. The first was fully controllable airship La France, whose propeller was driven by an electric motor. However, the main difficulty rested with the storage of electrical energy in bulky and heavy batteries. Even now, batteries are still too heavy to be used in general aviation aircraft as the main power source, except for aircraft with very short operating time like gliders. One aeronautical field in which electrical propulsion has become established over the past 20 years is for model aircraft flying. Progressive miniaturization of electrical and electronic components has shown the advantages of the technology. We must alsopoint outa number of largeaircraftdesigned andflown usingsolarpanelsas an energy source. References to the Pathfinder, Solar Challenger and phenomenal Solar Impulse demonstrate ability of new technology of propulsion. Also, the automotive industry has again become interested in electrical propulsion for environmental reasons. The search for clean power systems has led to the development of alternatives to the traditional lead–acid batteries. Developmentsin the automotiveindustry is also followed by aviation. Several companieshave displayed prototype aircraft using fuel cells (FC) or batteries.

The article deals with the assessmentof both types ofenergy sources and theirmutual suitability for light aircraft propulsion. Aim of this paperis not a detailed technical description of the aircraft propulsion system, but an objective evaluation of the advantage sand problems of various energy sources for electric propulsion.

Institute of Aerospace Engineering, Brno University of Technology (BUT) with contribution of JIHLAVAN Airplanes Company deal with this problematic by developing experimental aircraft VUT 051 RAY. The project aims oncreation of functional base for design and development ofelectric powered airplane.VUT051 airplane should verify integration of an electric drive system for small aircraft.The conceptis based on existing VUT 001 Marabu experimental aircraft, which was also developed and built by BUT. The aircraft under went comprehensive flight measurements, and its structure enables adaptationto electricpropulsion. VUT051 RAYis not the first aircraft with electric propulsion.Over the past few years, a number of aircraft with electric propulsion were presented.These aircraft were powered by batteries as well as from the fuel cells. The list of projects of electric aircraft with their basic performance characteristics is provided in Table 1. Goal of VUT051 RAY project is to prepare suitable (and practical) technical solution for future light electric powered airplanes. Difference fromsimilar projectsis the creation of operationally usable electric aircraft concept.

Table 1 – A list of recent project of electric aircrafts

Airplane	No. of seat	Wingspan [m]	Wing area [m²]	Mtow [kg]	Engine take-of performance [kW]	Endurance [hr]	Battery capacity [kWh]	Battery Weight [kg]	First flight
Electraflyer C	1	8,38	7	283	13,5	1-1,5	5,6	31	06/2008
Yuneec e430	2	13,8	9	430	40	2	13,32	83,5	06/2009
Apis EA2	1	15	12,2	370	40	0,26	8	55	08/2010
Electra one	1	8,6	6,4	300	16	3	3	100	03/2011
LZ Design FES	1	15	9,06	453	25	1	3,6	27	03/2011
e-VIVA	2	17	14,2	472,5	40	1,3	8,2	75	04/2011
Electrolight 2	1	15	11,7	315	19	1,5	5,55	34	12/2011
DynAero Lafayette III	1(2)	6,63	8,15	450	40	Not declare	17kW PEM FC + Li-ion	50+78 FC system	05/2004
HK36 Super Dimona	1(2)	16,3	15,3	700	54	0,33	25kW PEM FC +25kW Li-ion	Not declare	04/2008
SkySpark fuel cell	1 (2)	7,5	10	450	65	2	60kW PEM FC + Li-ion	Not declare	05/2009
Antares DLR H2	1	20	12,6	750	42	4,2	25 kW PEM FC + Li-ion	Not declare	07/2009
ENFICA - FC	1(2)	9,9	11,85	550	40	0,18	20 kW PEM FC +20 kW Li-ion	Not declare	05/2010

Table 1 documents the development of electrically powered aircraft. Aircraft powered by batteries as Yuneec430, Electraflyer C, ElectraOne are already commercially available on the market. Hydrogen powered airplanes represent only experimental prototypes. In terms of performance, both groups have comparable results. Battery technology has currently fast development and battery parameters are improving with each generation. However, the achieved performance does not allow longer flights. To achievethe same performance fifteen times better performance of batteries compared with gasoline is still needed. Energy density and power density of energy source represent an importan tparameter when selecting a suitable source of electric energy. The hydrogen fuel cell can increase the amount of stored energyby increasing the volume of the tank. This increase of a stored energy has a nonlinear dependence as a battery. Overview of technology options for each source is indicated in Figure 1.

The fuel cell itself has in contrast with battery very good parameters. In practice, however, these parameters are lower due to the installation of additional equipment necessary for operation of the FC. Also the operational characteristics of FC require an auxiliary battery for mobile applications.

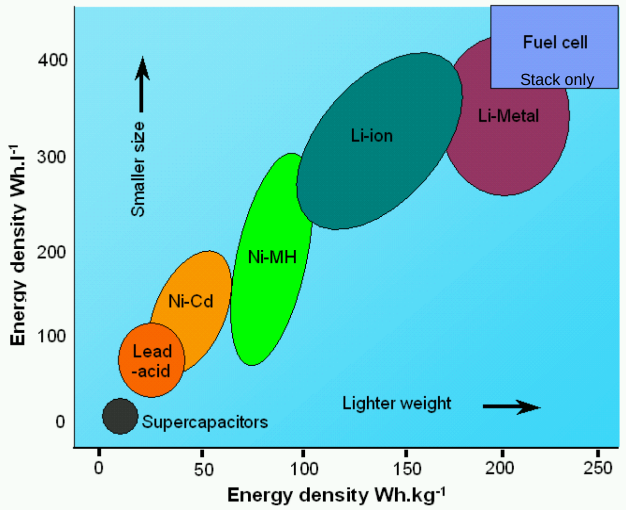

***Figure 1** – Specific energy and specific volume of rechargeable batteries and fuel cells.*

In terms of practical storage of electric energy, batteriesor hydrogen in combination with fuel cell can be used.Comparison of performance in terms of efficiency, safety and operational parameters of both, fuel cell and battery system was conducted on example of VUT 051 RAY airplane. Characteristics of this experimental airplane were considered to enable direct comparison of different means, how to store electric energy. **Primary intent of the paper is not to provide information on the VUT 051 RAY, but rather to compare practical aspects of utilization and safety aspects of fuel cells and batteries.** The airframe for VUT 051 RAY was taken and modified form the experimental airplane VUT 001 Marabu. The aircraft has combined structure composed of glass-fibre composite fuselage (with carbon-fibre reinforcement) and metal wing and horizontal tail unit. Original VUT 001 Marabu was powered by Rotax 912 combustion engine. The airplane has small front section and power unit in pusher-propeller arrangement to enable integration of new propulsion system close to the centre of gravity[1].

TECHNICALPARAMETERS OF THE VUT 051 RAY AIRCRAFT

Geometry:	Wingspan	9,9 m
	Length	8,1 m
	Height	2,4 m
Weights:	Max. take-off	600 kg
	Empty	390 kg
	Payload (pilot)	80 – 110 kg
Performance:	Max. design speed	260 km/h
	Econom. speed	95 km/h

***Figure 2** – VUT 001 Marabu airplane for conversion on VUT 051 RAY*

II. SAFETY ASPECT

Most electric airplanes present in table 1 were experimental projects, where special safety aspects for every day use of the aircraft were not considered. This part therefore describes potential risks for electric powerplant system and energy storage system.

Humanfailureis the most commoncause of accidentsin aviation.Pilotcan be the firstrisk ofelectric drive.

A pilot, who must understand the behavior of the aircraft and be able to control it, operates the aircraft. Thus, the pilot is an important stakeholder in the development process of power plant design and safety requirements. Typically, pilots have been trained in and have an operational license for a certain kind of aircraft. It will not only be difficult to readjust to a new kind of propulsion, but this readjustment process may take time. Accordance energy storage system has Depending on theenergy storage systemtochange the characteristicsof the propulsionsystem ofthe aircraft.The propulsionsystem basedonfuel cells isconsistent performanceover timein contrast,propulsionsystem basedon the batteryshows a decrease inavailable powerat the time. There are several factors in the aircraft's power system design that will impact the pilot directly. These include (but are not limited to):

- Ease of power control
- Similarity of aircraft control systems to those of other common aircraft in the light aircraft category
- Power plant system response to operator commands

When designingthe drive systemisnecessaryto consider the followingrisks:

ELECTRIC CURRENT

Foracceptableefficiencyof the propulsion systemis a necessary high voltage. Voltage exceeding 350V presents both an electrocution hazard and an ignition source for fuel contained in the vehicle or outside materials. Since a significant amount of the material used in aircraft construction is metal or carbon composite, with some degree of electrical conductivity, there is a high potential for electrical faults. This can pose a threat both in normal operations of the aircraft and especially in accidents. Even though most designs contain failsafe switches for the electrical system, these switches may be short-circuited if the aircraft is involved in an accident. Both AC and DC currents and shock are lethal; more DC current is required to have the same effect as AC current. Direct current tends to cause a single muscle contraction often strong enough to force people away from the current's source. The severity of the electric shock depends on the following factors: body resistance, circuit voltage, amplitude of current, path of the current, area of contact, and duration of contact. Conditions for a potentially, but more than likely, lethal shock across the heart are more than 375 V at a total body impedance of less than 5000 ohms and more than 75 mA and more than 50 J.

ELECTRICAL DRIVE SYSTEM

The electrification of the drive system can be a source of new dangers. Failure of auxiliary electronics for controlling the inverter can lead to a sudden loss of power. An extreme case may be reversing direction of rotation.

ELECTROMOTOR

Electromotor represents in drive chain coversion of electric energy to mechanicalpower. Electric powered planes typically use brushless type withpermanet magnets due to compromise between higher efficiency and low mass. Electromotor is optically more reliable device than combustion engine. There is no high temperature, moving parts, complicated fuel lubrication and cooling systems. Electromotor has only moving rotor with smooth rotation. Engine controller doesn't contain any moving parts and critical parts can be redundant for higher safety.

ENERGY STORAGE

For conventional aircraft energy storage system are fuel tanks, pipes and valves. Electric aircraft needs a source of electrical energy, which is muchmore complicated. Electricity is difficult to store. Unlike other common energy storage in prior use such as wood or coal, electricity must be used as it is being generated, or converted immediately into another form of energy such as potential, kinetic or chemical. For mobile systems can choose between the storage in batteries or fuel cells. Both energy sources have operational advantages but also weaknesses. The next section will compare properties of both types of energy sourcesin terms of safety.

HYDROGEN FUEL CELL

Hydrogen is a synthetic fuel. Pure hydrogendoes not occur in nature, for its productionis necessary some energy source. Hydrogen can be produced chemically from hydrocarbon compounds or from water by electrolysis. Hydrogenis not fuel but rather an energy carrier.

In fuel cells, gaseous hydrogen is combined with oxygen to water by the direct and continuous conversion of an externally supplied fuel and oxidant. This process is the reversal of the electrolysis of liquid water. Today exist various types of fuel cells, which use different electrolyte type and working temperature. For mobile applications are suitable fuel cells linked as Proton Exchange Membrane (PEM). They produce the most power for a given weight or volume of the fuel cell, and in addition also have good cold starts capability. Polymer Electrolyte Membrane (PEM) Fuel cell has Operating Temperature 50-100°C, typically 80°C. Table summarizes advantages and disadvantages of this FC type.

Table 2 *– Properties of PEM FC*

Advantages:	Disadvantages:
- Solid electrolyte reduces corrosion & electrolyte management problems - Low temperature up to 100°C - Quick start-up	- Expensive platinum catalysts - Sensitive to fuel impurities - Low temperature waste heat - Storage, the membrane of FC must by wet everytime

Operation, control, and monitoring of the fuel cell stack require several essential subsystems that as a whole form the balance of the plant. Thus, in addition to the stack itself, the complete fuel cell system, as shown in Figure 3, contains the following:

- Air supply. Oxidant must be supplied to the cathode at a specific pressure and flow rate. Air compressors, blowers, and filters are used for this.
- Water management. The inlet reactant gasses must be humidified, and the reaction product is water. Management of water must also consider relative amounts of the two phases. In aviation application is necessary to prevent icing of water at high altitude.
- Thermal management. Stack temperature must be monitored and controlled trough an active or passive stack cooling systems as well as a separate heat exchanger in the case of an active system.

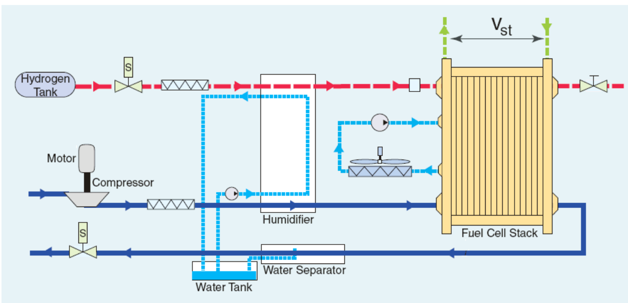

Figure 3 *– Scheme of fuel cell PEM type*

Hydrogenfuel cellshave a highinternal resistanceand behaveas a softvoltagesource.This isdifferent from batteriesthat have a lowinternal resistance. Batteries havebetter capatabilities to manage changes inloadsthan FC. Solutions with only FC (without batteries) have to be designed for maximum power. It requires large and heavy fuel cell stack with auxiliary unit. For example compact fuel cell system HeliocentrisHyPM HD16 with 16kW power has weight 115 kg. Mobile applications usually combine FC with battery as shown in table 1. For use of FC in airplanes, it is necessary to develop special light weight components of fuel cell system.

Hydrogen can be stored in the cryogenic tank or in the high pressure tank. Liquid hydrogen is not suitable for long-term storage and has not good energetic bilance, but energetic density is higher. High-pressure tanks are more suitable for mobile applications. Very high pressure is required due to low density of the hydrogen . Today's technological limit for pressure tanks is believed to be approx. 1000 bar. Typical pressure is 200 -350 bar. For mobile applications, composite pressure tanks with pressure up to 700 bar are developed. Storage in advanced materials (within the structure or on the surface of certain materials) represent athird way. Hydrogen storage in materials offers great potential, but additional research is required to better understand the mechanism of hydrogen storage in materials under practical operating conditions. [5]

SAFETY ASPECT OF FUEL CELL SYSTEM

Hydrogen has several properties that differ strongly from natural gas or methane. One of the other positive characteristics of hydrogen is that it disperses very quickly, meaning that hydrogen concentrations under normal pressure dissolve to incombustible levels very quickly. This also means that under ambient air pressure hydrogen has very little energy density per unit of volume compared to other vehicle fuels. Hydrogen also rises very quickly and therefore is less of a threat outdoors. Except in extremely high concentrations, hydrogen is not toxic to humans. Hydrogen is odourless and tasteless. While the flame of burning hydrogen is visible under daylight conditions, it is a lot less so than flames from other fuels due to the lack of soot. A hydrogen flame can be most easily identified by the mirage-like effect on the air over and around the flame, as it otherwise does not produce significant heat radiation. Hydrogen-air mixtures can ignite or explode at both lower and higher concentrations of the gas in the air than CNG or methane. Hydrogen is more easily ignited than other fuels. The impact of this is negligible, however, as most other fuels can already be ignited by small amounts of static electricity.

To store hydrogen in liquid form, it has to be cooled down dramatically. Hydrogen has a boiling temperature of only 20° Kelvin or -435° F. This causes the fuel to boil off very quickly when spilled, creating only a narrow window for ignition. On the other hand, the intensely cold fuel can cause serious cold burn damage to people and embrittle and break metal equipment in particular. In enclosed locations with normal temperatures, spilled liquid hydrogen will create enormous gas pressures, tearing apart vessels without safety valves.

AVAILABLE SAFETY STANDARDS

Theuseof fuel cells inaviationisdeveloping standards EUROCAE WG80 / SAE AE-7AFC - Aircraft Hydrogen Fuel Cell Systems Thisstandard is intend to develop guidelines to support qualification and certification of hydrogen fuel cell systems for civil aircraft applications for Large airplane category CS-25.

STORAGE OF AIRPLANE

Hangaring a hydrogen airplane or other gas-fueled airplane in an enclosed structure is a serious safety concern. Hydrogen's tendency to rise and disperse rapidly makes this the only situation in which small leaks can create extremely dangerous situations. In normal operation,it is necessary toequip thehangarshydrogendetectorsandventilation system

BATTERIES

Batteries operate by converting chemical energy into electrical energy through electrochemical discharge reactions. Batteries are composed of one or more cells, each containing a positive electrode, negative electrode, separator, and electrolyte. Cells can be divided into two major classes: primary and secondary. Primary cells are not rechargeable and must be replaced once the reactants are depleted. Secondary cells are rechargeable and require a DC charging source to restore reactants to their fully charged state. Primary batteries have the highest energy density. Although the secondary (rechargeable) batteries have improved, a regular household alkaline provides 50% more power than lithium-ion, one of the highest energy-dense secondary batteries. [3]

Advantage of secondary batteries is low internal resistance. This allows high current on demand, an attribute that is essential for traction.The lithium based batteries have three times higher energy density compared to other systems like nickel metal-hydride and nickel-cadmium. Therefore, Lithium-ion (Li-ion) batteries are attractive for electric aircraft applications because of theirrelatively high energy densities per unit mass, volume, and cost. Advantages and limitations of two main types of lithium-based batteries are in table 3.

***Table 3** – Properties of Li-based batteries*

Advantages and Limitations of Li-ion Batteries	
Advantages	High energy density — potential for yet higher capacities. Relatively low self-discharge — self-discharge is less than half that of NiCd and NiMH. Low Maintenance — no periodic discharge is needed; no memory.
Limitations	Requires protection circuit — protection circuit limits voltage and current. Battery is safe if not provoked. Subject to aging, even if not in use — storing the battery in a cool place and at 40 percent state-of-charge reduces the aging effect. Moderate discharge current. Subject to transportation regulations — shipment of larger quantities of Li-ion batteries may be subject to regulatory control. This restriction does not apply to personal carry-on batteries. Expensive to manufacture — about 40 percent higher in cost than NiCd. Better manufacturing techniques and replacement of rare metals with lower cost alternatives will likely reduce the price. Not fully mature — changes in metal and chemical combinations affect battery test results, especially with some quick test methods.

Advantages and Limitations of Li-ion Polymer Batteries	
Advantages	Very low profile — batteries that resemble the profile of a credit card are feasible. Flexible form factor — manufacturers are not bound by standard cell formats. With high volume, any reasonable size can be produced economically. Light weight – gelled rather than liquid electrolytes enable simplified packaging, in some cases eliminating the metal shell. Improved safety — more resistant to overcharge; less chance for electrolyte leakage.
Limitations	Lower energy density and decreased cycle count compared to Li-ion — potential for improvements exist. Expensive to manufacture — once mass-produced, the Li-ion polymer has the potential for lower cost. Reduced control circuit offsets higher manufacturing costs.

Li-pol secondary batteries are currently the best energy storage devices for portable consumer electronics, in comparison with other conventional batteries, because of the high energy density as shown in Fig. 3. They were first developed and commercialized by Sony in 1990. Since market introduction, there was 3-times the increase in capacity (until today). This remarkable increase in capacity was realized through engineering improvements in the manufacturing processes and the introduction of new separator, cathode and anode materials and still exists potential for further improvement.

Major problem of Lithium-ion (Li-ion) batteries is charging process sensitivity. Exothermic chemical reaction can start in the cell when its terminal voltage is overcome. This is very dangerous due to the risk of fire. Lithium based batteries are classified as dangerous stock for air transport. Therefore batteries need special protection circuit (battery management system) for balancing voltage on each battery cell.

SAFETY ASPECT OF BATTERY SYSTEM

Batteries are generally safe. Modern lithium based batteries contain highly reactive chemicals that will react at elevated temperature by default. Li-ion batteries using conventional metal oxides are nearing its theoretical limit on specific energy. Rather than optimising runtime, battery makers are improving manufacturing methods to enhance safety and increase the lifecycle. Overheating of cell can cause an exothermic reaction and explosion. Hot gases and chemicals can hazards to human health. With regard to throat and stomach issues, ingestion of the solution in the battery's cells along with ingesting cobalt itself, which is a known carcinogen, can be harmful to the delicate tissues of the throat and stomach as well as become a cause for cancer in the affected areas. Skin issues can also be a result of exploding lithium ion batteries. Additionally, handling of batteries that are leaking the material from the cells can cause both allergic reactions and severe burns to the skin.A fire with batteries containing lithium metal requires a special extinguishing method.

AVAILABLE SAFETYSTANDARDS

To address some of the safety risks associated with the use of lithium-ion batteries, a number of standards and testing protocols have been developed to provide manufacturers with guidance on how to more safely construct and use lithium-ion batteries. Product safety standards are typically developed through a consensus process, which relies on participation by representatives from regulatory bodies, manufacturers, industry groups, consumer advocacy organizations, insurance companies and other key safety stakeholders. The technical committees developing requirements for product safety standards rely less on prescriptive requirements and more on performance tests simulating reasonable situations that may cause a defective product to react. The following standards and testing protocols are currently used to assess some of the safety aspects of secondary lithium batteries:

Underwriters Laboratories

- UL 1642: Lithium Batteries
- UL 2054: Household and Commercial Batteries
- UL Subject 2271: Batteries For Use in Light Electric Vehicle Applications
- UL Subject 2580: Batteries For Use in Electric Vehicles
- UL 2575: Lithium-Ion Battery Systems for Use in Electric Power Tool and Motor Operated, Heating and Lighting Appliances

Institute of Electrical and Electronics Engineers

- IEEE 1625: Rechargeable Batteries for Multi-Cell Mobile Computing Devices
- IEEE 1725: Rechargeable Batteries for Cellular Telephones

Society of Automotive Engineers

- J2464: Electric and Hybrid Electric Vehicle Rechargeable Energy Storage Systems (RESS), Safety and Abuse Testing (revised 2009) [10] which adopted test procedures from the *Sandia National Laboratories Electrochemical Storage System Abuse Test Procedure Manual* as a basis for a body of tests which may be useful for abuse testing of electric or hybrid electric vehicle batteries
- J2929: Electric and Hybrid Vehicle Propulsion Battery System Safety Standard — Lithium-based Rechargeable Cells[11] published In February 2011 and describes performance criteria for some of the tests described in SAE J2464.

International Electrotechnical Commission

- IEC 62133: Secondary Cells and Batteries Containing Alkaline or Other Non-acid Electrolytes — Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made from Them, for Use in Portable Applications
- IEC 62281: Safety of Primary and Secondary Lithium Cells and Batteries During Transportation

Battery Safety Organization

- BATSO 01: (Proposed) Manual for Evaluation of Energy Systems for Light Electric Vehicle (LEV) — Secondary Lithium Batteries

The most common product safety tests for lithium-ion batteries are typically intended to assess specific risk from electrical, mechanical and environmental conditions. These standardscan be usedas a basisfor evaluatingthe suitabilityof batteriesfor aircraft propulsion systems.Table2comparesavariety ofstandard and testprotocol.Testcriteriawere chosenwithregard to theuse of batterieson board ofaircraft.

STORAGE OF AIRPLANE

Storage of airplane with high capacity batteries should not pose ahigherriskthan conventional aircraft. Slow charge the battery during hangaring will have to be monitored and will have to be made suitable fire precautions. The airport will have to been sure dextinguishing media appropriate for th ehigh-voltage battery.

III. CONCLUSION

In the case of electrically powered aircraft, the system energy storage limit of defending their operational expansion. Currently, exploring two main ways of storing energy: hydrogen or batteries. Both solutions have their advantages and disadvantages. Aim of this article was to compare both ways from safety operation aspects.

The propulsion system using only the fuel cell can be safer than a system using batteries as energy storage. Most electrically powered aircraft with fuel cell also uses the auxiliary battery to overcome energy peak demand. A system based only on the fuel cellsis difficult to realizefortheir characteristics. Therefore, this energy storage system contain more risky components that connect the disadvantages of both examined solution of storing energy. Fuel cell system also has a number of moving mechanical components that can reduce overall system reliability. The advantage ofthe fuel cellisa quick and safe release of stored energy.

Energy storage system using only battery is much easier, but to replace combustion engines by electric motors powered by batteries with similar weight and performance of overall propulsion system, ten fold higher energy density of batteries would be required. There are not moving mechanical components that can fail. The battery consists from a large number of articles, and incase of failure ofone cell does not occur failure of the battery pack. The main problem is the sensitivity of cell stoover voltage or intensive discharge which may lead to an explosion cell. This problem can be solved by battery management. The advantage is simplicity without the use of mechanical components such as a compressor or a pressure vessel. The disadvantage is the inability to quickly and safely release the stored energy.

Despite the certain benefits of energy storage system based on fuel cell, are these system operationally expensive. In the future is expected to use a new type of battery working on a similar principle as the fuel cell. The practical application of this concept is expected in the longterm. By this time, it is necessary to work on the new safety standards and gain operational experience with electrically driven aircraft like the VUT 51Ray.

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RNAV PROCEDURES COMPUTER VALIDATION

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Abstract *– This article focuses on RNAV instrument procedures computer validation using Eurocontrol tool RVT (RNAV Validation Tool). This complex tool provides much functionality for testing of new TMA procedures such as STARs, SIDs, approaches etc. Article also shows practical use of RVT on the new RNAV STAR procedures layout to the Kunovice airport.*

Key words – RNAV, SID, STAR, validation, Kunovice, altitude, runway, waypoint

I. INTRODUCTION

The validation stage is an important part of every project. In the case of introduction of new procedures for an airport, validation follows the construction phase. There can be used variety of tools to validate the procedure construction. In general, it depends on what type of validation is intended. In the construction and implementationproject of RNAV procedures at the Kunovice airport are intended following kinds of testing:

- Operational simulation
- Testing of construction

The operational simulation means that the proposed construction will be subject of fast time simulation testing. Expected outputs of the simulation are parameters such as flight time, capacity or delay. For PBN procedures operational simulation, the model and test scenarios in Visual Simmod have been prepared. Results are going to be presented in some of future articles.

Testing of RNAV procedures constructions focuses on particular elements of each procedure. These elements include turns parameters, maximum speed in relation to minimum stabilization distance, vertical constrains etc.

While operational simulation aims to test overall traffic situation, the construction test has to check flyability of particular procedure.

II. RVT – EUROCONTROL VALIDATION TOOL

RVT (RNAV Validation Tool) is a product of development by DW International for Eurocontrol purposes. The main objective of this development was to provide software for RNAV procedures validation, which can be used widely by ATM procedures designers. The result is a desktop application with variety of useful features [1].

The RVT works in two general modes:

- Procedure definition
- Trajectory display

The function of the definition mode is to enable creating aerodrome, runway and procedure legs and parameters within each procedure leg. RVT automatically provides validation test results immediately after every procedure change is saved. Algorithms called validators provide tests. The groups of tests are listed in Figure 1.

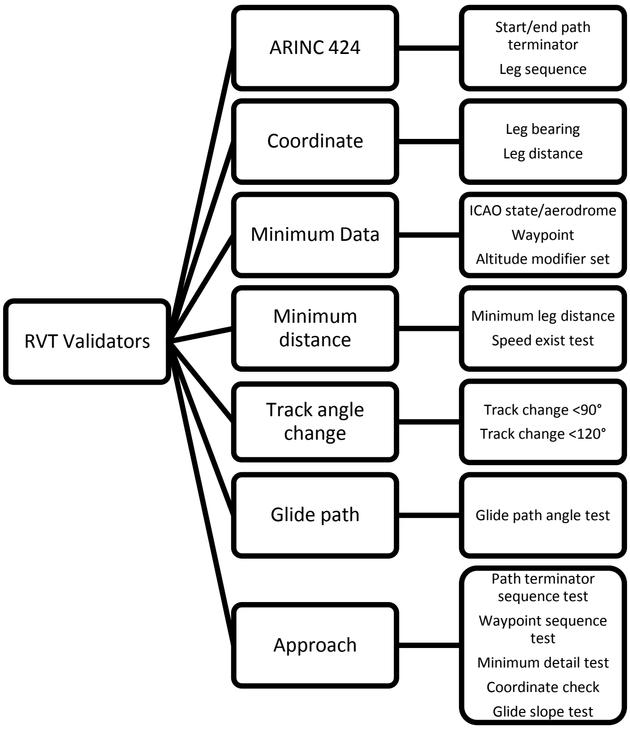

Figure 1 *- RVT Validators and tests*

To comment all above-mentioned tests is beyond the scope of this article. The important note is that there are three possible result types of each test – PASS, WARN and FAIL. If occurs result FAIL, there would be changed leg parameter followed instruction in the message column of validation result window. Result window also refers to a leg, segment or procedure, which failed.

Trajectory display is the second mode of RVT. Its basic function is to give an overview of procedure defined in the previous mode. Trajectory display can simulate a flight of predefined aircraft along procedure validated in procedure definition mode. Besides predefined aircraft and trajectory, there is also possible assignation of weather grid in seven altitudes (0, 1000, 5000, 10000, 15000, 20000 and 25000 feet). The RVT also provides possibility for users to define weather grid modifying wind parameters (magnitude and direction) and temperature deviation from ISA.

RVT also gives users the option to preset their own aircraft model. In RVT, aircraft model is identified by its own original call sign for each procedure. The model is described by takeoff weight, landing weight, cruise altitude, cruise speed, entry/exit altitude and aircraft type. The aircraft type parameter consists of aircraft category and type of propulsion (J-Jet, P-propeller). The aircraft adjustment of parameters is enabled via call-sign editor shown in Figure 2.

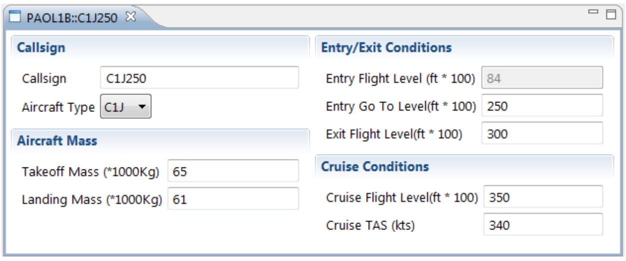

Figure 2 *- Call sign editor*

Once the procedure is defined and validated, weather grid and required aircraft is set, RVT allows trajectory calculation. The results of trajectory calculation are a flight vertical profile with projected terrain and 3D projection of the trajectory in trajectory view window. Both vertical profile and trajectory can display multiple trajectories, which results in possibility to compare generated tracks with changing aircraft type, wind or temperature. Another available functionality is the trajectory flight animator, which provides an animation of flight along the calculated trajectory simultaneously in both trajectory view and track profiler. Each of the trajectory calculation also generates *.kmz data file format usable for example in Google Earth or it can be converted into the plain text for other use.

III. RNAV STAR SOFTWARE VALIDATION

At this stage of the article an example created in RVT with one sample RNAV procedure for Kunovice airportwill be presented. For this purpose of newly designed standard instrument arrival (STAR) MAVOR 1Swas chosen. Although the shape of MAVOR 1S and others RNAV STARs to Kunovice were presented in a previous articles [2], it underwent several modifications. Its current design is depicted in Figure 3. The example is divided into two parts. First part focuses on procedure definition in RVT and its successful validation. The task of thesecond part is to test the procedure using trajectory calculation under various conditions (for example various aircraft type, changing wind direction etc.).

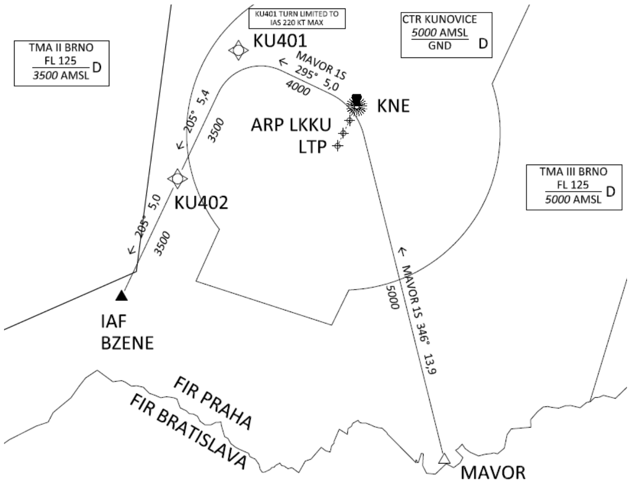

Figure 3 *- MAVOR 1S RNAV STAR procedure*

PROCEDURE VALIDATION IN TRACK DEFINITION MODE

Procedure definition and validation starts with creation of aerodrome, runway thresholds adding information like name, geographical location and elevation. After we have runway threshold defined there is no problem to enter SID, STAR or Approach procedure. Each procedure is in RVT divided into legs, which always represent one end waypoint and trajectory from the previous waypoint. The required parameters for MAVOR 1S STAR are listed in the Table 1. All parameters seem to be clear, however, it would be appropriate to explain the term path terminator. The path terminator is a two-letter code describing a flight path along all segments of RNAV procedure and a specific type of termination of procedure leg. It should be noted, that path terminators are assigned to all RNAV procedures segments in an aircraft navigation database [3]. In case of our example, there were used path terminators for initial fix (IF) and track to a fix (TF) path terminator. TF defines geodesic straight path between two waypoints. It also stands for clarification the meaning of predecessor in the altitude column. Predecessor +/- means altitude constraint “at or above” respectively “at or below”. The predecessor @ means “at altitude”.

At the moment, the procedure RNAV STAR 03C MAVOR 1S as defined in Table 1 has been validated with no FAIL result.

Table 1 *- MAVOR 1S RNAV STAR*

MAVOR 1S						
Path descriptor	**Waypoint name**	**True course**	**Altitude [ft]**	**Speed limit [kt]**	**Distance [NM]**	**RNAV TYPE**
IF	MAVOR					RNAV 1
TF	KNE	346.045	+5000	250	13.9316	RNAV 1
TF	KU 401	295.318	+4000	250	5	RNAV 1
TF	KU 402	205.255	+3500	220	5.4174	RNAV 1
TF	IAF BZENE	205.255	@3500	220	5	RNAV 1

TRAJECTORY CALCULATION IN TRAJECTORY DISPLAY MODE

As soon as the procedure is validated, RVT enables trajectory calculation under variable conditions. For purpose of this article, it will be created trajectories for three most represented aircraft types for each A, B and C category allowed to operate at the Kunovice airport. The aircraft types and their RVT description are listed in the Table 2.

Table 2 *- RVT aircraft models description*

Category	Type	Propulsion	TOW	LAW	Cruise FL	Cruise speed [kt]
A	L410	P	6600	6400	210	200
B	C25B	J	6291	5783	430	360
C	C680	J	13959	12508	470	430

To simplify, all simulations will be made in no wind conditions with temperature deviation from ISA +15°C. It is expected that compared trajectories will differ in the turns at KNE and KU401 waypoints. The difference in comparison to the nominal trajectory will increase with aircraft speed and actual weight. The faster and heavier aircraft will begin its turn earlier due to higher turn radius than slower and lighter aircraft.

The metric of comparison is the orthogonal distance between waypoint KU401 and simulated trajectory(see Figure 4).

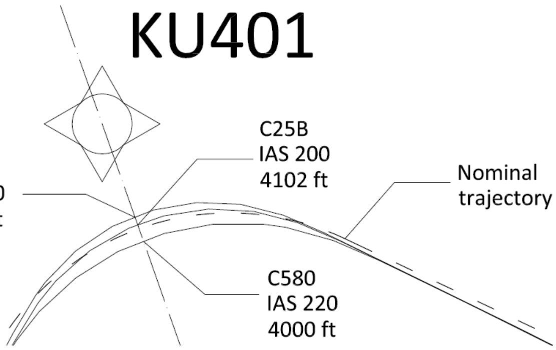

Figure 4 *- Calculated trajectories comparison*

The distance to a nominal track for each trajectory was performed in AutoCAD software, where the trajectories were transferred from *.kmz format using online gps converter tool [4]. The measurement results shown in the Table 3 has met our expectations that faster and heavier aircraft has to begin its turn earlier in comparison to a smaller aircraft, which resulted in higher orthogonal distance to KU401 waypoint at the metering point. It is also obvious that all three simulations are within lateral 1 NM accuracy requirement.

Table 3 *- Calculated trajectories analyses*

Category	Type	Propulsion	IAS [kt]	Distance [NM]
A	L410	P	140	0.66
B	C25B	J	200	0.72
C	C680	J	220	0.84

Vertical profile of simulated trajectories depends on aircraft model as well as on altitude constrains and predefined vertical path angle. There is an assumption that slower and lighter aircraft is more flexible in vertical operations due to its lower inertia. Initial altitude was set to all three trajectories to flight level 100 (10000 ft). The speed limits and altitude constrains were set to values presented in Table 1.

Profiles plotted in Figure 5have confirmed the assumption that aircraft type of lower category will be more flexible in vertical direction. It is well recognizable from L410 profile, which starts its descent distinctly later than the B and C profiles.

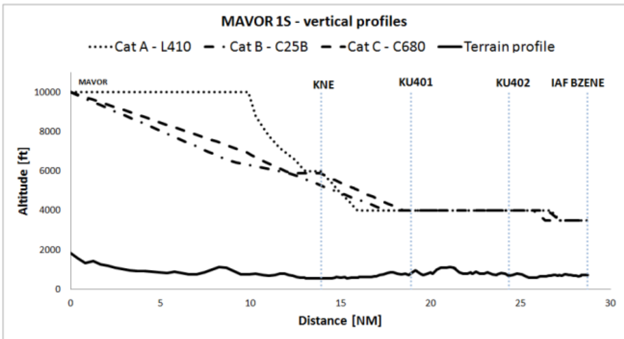

Figure 5 *- Calculated trajectories vertical profiles*

IV. CONCLUSION

The article aims to present partial results of effort to reorganize the Kunovice airport airspace. It describes a validation phase of introduction RNAV procedures at LKKU. For this process RNAV Validation Tool (RVT)was used, the desktop application developed for Eurocontrol.

RVT has two basic modes. The first one enables procedure definition and its immediate validation. The validation tests are based on algorithms called validators. The validation results are simple pass/fail checks and it is provided for every leg of tested procedure.

Second RVT mode allows to an user calculation of several trajectories of validated RNAV STARs, SIDs or approaches under various conditions such as different aircraft types models or weather conditions. Calculated trajectories can be exported to Google Earth or other applications compatible with .*kmz data file format.

This article shows an example of RNAV STAR to Kunovice validation in RVT and analyzes three aircraft categories simulated trajectories under constant weather conditions.

There are other possibilities of using, which are provided by RVT. Let's mention for example obstacle assessment studies or interaction of terminal area procedures in multiple airport environments.

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AVIATIONEXAMTEST PREP SOLUTIONS

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Abstract – *Aviationexam offers a solution to fill the gap between pilot ground preparation and the official exams by linking the theory with a realistic simulation of the exam environment through the interactive Test Prep system. Variability of the system, which can be used online and also offline through proprietary applications for most smart phone and tablet platforms, provides a significant freedom while studying. The system provides an option to evaluate the student's knowledge and verify if the student is ready to sit the official exams. The explanations and comments, which are provided for each question, turn the system into a very effective study tool, which can be used by individual users or Training Organizations.*

Key words – Aviationexam, application, exam, ATO (FTO), preparation, Test Prep system, theory, training, study, student

I. INTRODUCTION

When learning to fly, the flying part is the attractive one to most future pilots. The theory has the same importance, but students usually prefer the cockpit over the classroom. Even for those students, who put an extra additional effort into mastering all of the theoretical aspects of their training, there is usually a large gap between their theoretical preparation and the knowledge they are expected to demonstrate during the official written exams. The reasons for this gap may be multi-fold: arising from situations such as large fragmentation of training materials; failure of some training materials to cover the entire syllabus down to the required detail or the student's unfamiliarity with the scope of the Learning Objectives for the exams from given subjects.

Aviationexam offers a solution to fill the gap between the theoretical preparation and the scope of the official exams by linking the theory with a realistic simulation of the exam environment through the interactive Test Prep system. Bringing the theory closer to the practical application and evaluation of the student's knowledge are the great benefits of the Test Prep system, while the brief explanations of each test question together with comments from other students turn the system into a well respected study tool.

II. TEST PREP SYSTEM

The Test Prep system of Aviationexam offers:

- *ATPL, CPL, IR Question Database*
- *Possible Answers with Key*
- *Explanations*
- *Picture Supplements (Questions)*
- *Picture Supplements (Explanations)*

Using question banks in the process of a pilot's theoretical preparation appears to be a somewhat controversial topic. At this place, it should be clearly stressed, that the Aviationexam Test Prep system is not intended to serve as the only means of student preparation and source of essential information for the EASA examinations. Instead, its purpose is to serve as a very effective tool to assist in getting familiar with the content of the examinations and to verify if the student is ready to sit the official exams. The Test Prep system should be used in conjunction with other training materials, ground training courses or instructor guidance.

The Test Prep system was intended and developed as a study tool:

All questions in the database contain an explanation why the respective answer is the correct one.

Commenting on a specific question in the database is another educational feature of the Test Prep system. Comments are primarily intended for users to discuss anything concerning the specific question amongst themselves (users <=> users). Aviationexam is doing their best to monitor the student comments and provide responses where able.

The extensive "Reports and Statistics" module helps to identify the weak areas of individual students and allows the students or their instructors focus on these specific areas at a greater depth.

Marking questions with flags "For review", "Keep testing", "Show 1x in the next test", "Don't test" helps with navigation between the questions.

The absence of the possibility to display a concise list of all questions together with the correct answers (like a "cheat sheet" format) and advanced features allowing shuffling the answer possibilities, prevent the students from plain rote memorizing of the correct answers.

DIFFERENT PLATFORMS

The system is available as an online system and also through applications, which don't require constant internet connection.

- *OS X application*
- *iPhone/iPad application*
- *Android application*
- *MS Windows software*

Synchronization between all platforms is supported. As the smart phones and tablets are the big phenomena of these days, it is mainly the iPhone/iPad app and app for smart phones and tablets with Android, which make the Test Prep system attractive to many students. Studying while using phone or tablet brings the comfort and possibility to study anytime and anywhere, without the need to be connected to the internet.

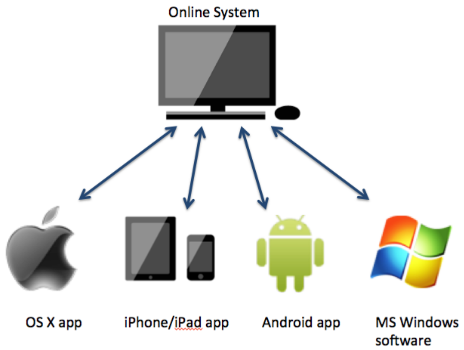

Figure 1 *– Synchronization*

Why synchronization? The database of the questions, which is available through the online Test Prep system, is updated continuously. Synchronization enables downloading the updates to respective devices when using offline applications. The Test Prep system uses advanced features to generate new tests from questions, which the student has not seen before or the ones, which were answered incorrectly in previous tests. These features are based on a detailed analysis of the user's testing history. When using Test Prep system through multiple devices it is still possible to benefit from these features – the complete student's testing history and also flags get synchronized during the synchronization process.

Learning Management System

The Test Prep system is not intended for individual students only. Special module of Aviationexam Test Prep system for Training Organizations – Learning Management System (LMS) can make the ground training more effective and it brings the distance learning option. The ground instructors are able to manage individual student accounts (create, delete, modify), completely manage the access of the student to the system, monitor student progress and identify his/her weak areas, access a complete testing history + detailed reports for any individual student or for a group of students organized into a specific course, etc.

The LMS also provides the training organization with the means of scheduling, administering and automatic grading of any required progress tests for the students. It is possible to setup a series of progress tests (or required practice tests) for their students in a sequence, define a detailed content and testing parameters that correspond to the training organization's specific ATPL, CPL or IR syllabus. The LMS allows full customization of all parameters that the training organization may need to modify to adjust the testing structure and/or content to fit their specific needs (passing scores for tests, test parameters, test content, etc.).

III. Conclusion

As said above, the training courses and instructor guidance has an irreplaceable role in the pilot ground training process. Using the Test Prep system in conjunction with the traditional training materials brings benefits for both the students and the instructors.

Instructors: Instructor can see detailed report of each student's performance and can easily detect the most problematic areas of the student. Based on these results, he/she can adjust the lessons and provide appropriate guidance. Creating study plans for the whole groups of students and using eLearning features of the Test Prep system makes the administration of the entire course much more effective.

Students: When using interactive Test Prep system, the extensive statistics and reports help the students find out how would they succeed at the official exams. The applications for smart phones and tablets give a chance to study anytime and anywhere. Explanations for each test question save the students a lot of time, because they don't have to search for the right page in the study book. And if there is a need for consultation, the user comments are the right place where to look at.

For these and many other reasons, the Test Prep system by Aviationexam has already earned its place on the list of traditional ground training tools utilized by thousands of students all over Europe during their pilot ground preparation. This is evidenced by countless positive testimonials and growing number of training organizations using Aviationexam Test Prep system.

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PROGRESS OF FIBER COMPOSITE REPAIRS IN AIRCRAFT CONSTRUCTION

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Abstract *– Advanced composites and bonded materials have revolutionized modern aircraft construction. Today they are routinely used in thrust reversers, engine cowlings, flight control surfaces, radomes and other secondary structures. But new generation aircraft like the A380, B787 and A350 also use fibre composites in large primary structure components like the fuselage or the center wing box that can not be removed for damage assessment and repair. In 2012 an investigation detected operational deficits in the area of repair of fibre composite aircraft components. This article will show the progress in this area after gaining more than one year of operational experience with the Boeing 787.*

Key words – Autoclave oven, bolted repair, bonded repair, composite repair, cure, damage assessment, doubler, experts, fibre composites, fuselage, handling difficulties, impact damage, improvements, maintenance, monolithic, qualification, structural damage, structural skin, training concepts, workshops, .

I. INTRODUCTION

The advantages of composites in aircraft construction are the excellent ratio of strength to mass, the excellent fatigue and corrosion resistance and malleability which allow a precise design according to design requirements. With composites it is easier to produce complex shapes than using metal. A complex component does not need several individual parts anymore and therefore requires fewer fasteners which are frequently the weak area of a structure. By replacing metallic materials by fibre composites basically up to 40% of the mass can be reduced. These savings which in turn have a positive effect on fuel consumption and payload of the aircraft represent a major ecological and economic advantage, especially in a market environment with high fuel prices and tougher emission standards for aircraft. Apart from the lower mass compared to conventional materials the fibre composites convince also by a high degree of reliability which allows lower operating costs [4]. But unfortunately where is light is also shadow. Disadvantages of fibre composites for the operator of the new aircraft generation are the restricted repair procedures and in addition to this, fibre composites are more vulnerable to damage in certain situations such as hail, lightning and bird strikes or collisions with ground service vehicles [7][7]. Furthermore, the restricted assessment possibilities as well as the less experience in dealing with fibre composites (maintenance staff) makes it very difficult to successfully assess and repair any damage and are essential disadvantages for the aircraft operation [5]. Therefore repairing and overhauling these delicate technologies both cost-effectively and in a durable manner is no easy matter. From experience from the flight operation it is to say that handling difficulties during aircraft operation arise in the areas of:

- Effortful and restricted repair procedures
- Restricted assessment possibilities
- Less experience in dealing with fibre composites

This article deals with the problem composite repair and will show the progress and improvements in this area.

II. Problem-state in 2011

With the introduction of the A380 into service and the B787 in final development phase the question came up if the maintenance is ready and able to face this new material technology with its difficulties for the maintenance. In 2011 an empirical survey (PhD research) obtained the experts general assessment in handling fibre composites during regular aircraft operation. Maintenance technicians, maintenance engineers, pilots, trainers, specialists in this area at research institutions (universities) and specialists in the field of airports were defined as experts in the areas of aircraft maintenance and aircraft operation [8]. The empirical study was supported by 119 experts from 6 countries and from different areas (airlines, aircraft operators, universities, airports and aircraft manufacturers). The results of the survey were revealing but also alarming since several deficits were identified. In assessing the cost of repairing damaged parts made of composite materials most of the experts expected increasing costs due to the effortful and restricted repair procedures.

Likewise, an increase in the time required for damage repair of fibre composites was expected by the experts which leads inevitably to higher costs of the whole process. In the area of training and practice of technicians in handling fibre composites there was a strong indication for the need of improvement identified by the experts. It was recognizable that the airlines, maintenance companies and training organizations had to develop and implement new training concepts to improve the knowledge of technicians to meet operational needs and requirements to perform composite repairs. In summary the result of the survey suggested that due to the increased use of components made of composite material, maintenance problems(damage assessment and repair) were expected at least in a transitional phase.

Meanwhile the A380 is in service for more than 5 years and the B787 for more than 1 year and the question must be answered if there are major improvements visible in the area of repair or if there are any new findings available compared to the knowledge of 2011.

III. Improvements in the area of composite repair

The aim of the maintenance is still to assure the save technical function of the aircraft and to deliver it as fast as possible for service after any repair. Repair speed is an important factor due to the fact that costs up to $100,000 per day arise for an unscheduled aircraft on ground (lost revenue) [6]. According to the Commercial Airline Composite Repair Committee an average permanent composite repair takes roughly 15 hours and therefore insitu composite repairs can cause severe aircraft delays and cancellations. Also the effort of a repair increases with the load the fibre composite component is exposed to as well as the qualification requirement of the technician increases. Permanent bonded repairs of very loaded components are not authorized at room temperature [9]. They must be cured, therefore a repair at the apron or the ramp is still very limited only or not possible at all [1]. The cure for permanent repairs are ranging from 250°F/121°C to 350°F/177°C and are generally performed by composite specialists at specialized workshops [6][9] therefore the removal of the parts with the subsequent processing in the workshop is still the consequence.

In the area of bonded repair procedures there are small improvements visible. Of course due to the general material composition of fibre composites the bonded repair is still effortful but some maintenance companies have specialized in composite repairs already. With the help of a significantly expanded workshop facility like new autoclave ovens it is meanwhile possible to perform repairs on large components made of composite material which could not have been possible a few years ago. For example the new autoclave oven in the Hamburg-based ARC® shop of Lufthansa Technik has an interior diameter of five meters, making it possible to cure fairings from even the largest jet engines as well as large flap systems from aircraft wings and radomes after these components have been repaired. But unfortunately a fibre composite fuselage manufactured in integral construction style like the Boeing 787 (Fig. 1) can not be removed from the aircraft and therefore needs other repair possibilities. Also the fuselage is most frequently affected by damages during the daily operation because of its dimension as well as its location.

***Figure 1** – The nose section of the Boeing 787*

The fuselage contains most of the access doors which can be seen as a damage hot spot. More than 50% of the total impact damages occur to the fuselage and primarily the door areas are affected which are endangered by the turn around activities while loading and unloading passengers, freight, catering etc. on the ground. Only new delivered airplanes do not show any damage in these areas in contrast to the older ones where many damages can be found. During impact damage investigation on 77 aircraft there were a total of 1324 impact damages found (Fig.2) [3]. Here the full spectrum of scratches in the paint up to considerable structure damages can be found (Fig. 3).

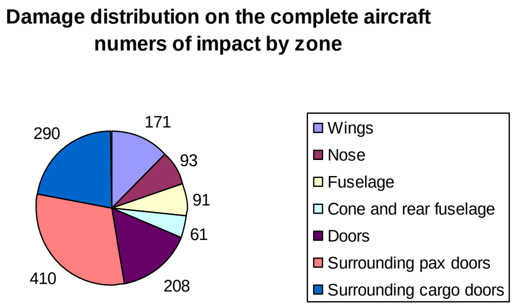

***Figure 2** – Impact damage distribution at the aircraft*

***Figure 3** – Ground handling impact by passenger boarding bridge*

To be able to repair damages on large components like the fuselage where the component can not be sufficiently cured after the repair the composite bolted repair is used. Meanwhile for structural skin repairs on monolithic parts Airbus focus on bolted repairs as definitive permanent repair [2]. Therefore this type of repair is the only possibility to regain the originally strength for the fuselage after any damage. Advanced bolted repairs of fibre composites components will be performed in the same way as bolted repairs of metal components. In a bolted repair a doubler is mechanically fastened around the damaged area (Fig.4+5). But fasteners will also create stress concentrations that can degrade the performance of the structure. Today fibre composite bolted repair has already been service proven on most aircraft types. Bolted repairs are damage tolerant, permanent repairs and these repairs typically would be carried out using a titanium doubler. The aircraft manufacturers have also successfully tested carbon fibre patch materials and specifying aluminum as an additional option. But with aluminum additional steps have to be taken to inhibit a galvanic connection between the aluminum and carbon fibre material [6] therefore aluminum is only the second choice.

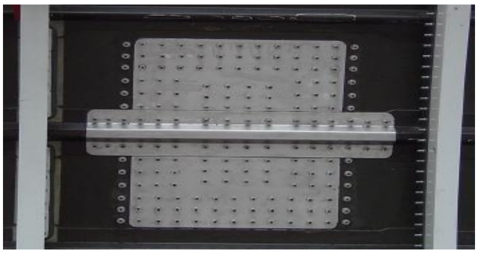

Figure 4 *– Bolted fuselage stringer repair*

Figure 5 *– Fuselage skin repair with large external doubler*

As an important improvement the further development and certification of repair kits built from fibre composites material has to be named and will be in future an important choice for most of the bolted composite repairs. This is partly because both the damaged component and the repair doubler is build from the same material with corresponding similar material behavior like the coefficient of expansion for example and also because it is possible to produce doubler also for concave or convex curved surfaces. The major improvement of this repair type is to provide exactly prefabricated repair kits for different areas of the aircraft. This results in a decisive time advantage and delivers the aircraft more quickly for service after a composite repair. The prefabrication process also assures the best fit of the repair doubler. Through the resulting simplified assembly cost savings can be achieved and the quality of the repair is increased. The bolted repair method is in contrast to the cure repair applicable outside the specialized workshops and far away from the maintenance bases which is a major advantage for the aircraft operation. Also a bolted repair requires less repair equipment compared to a cure repair and also the skills that are required to perform the repair are less extensive as those that are required for the cure repair. Therefore also less qualified technicians fare away from the specialized workshops of the maintenance bases are able to successfully perform a composite repair. Unfortunately the storage effort for the maintenance repair organizations will increase due to the many different specially formed repair kits but this is an acceptable disadvantage compared to the many advantages.

IV. Conclusion

Summarized it can be said that in the area of composite repairs a level has been reached, which allows to successfully perform repairs on high loaded large aircraft composite components in a reasonable time. On the one hand this is possible today due to the specialization of the maintenance organizations in fibre composite repairs accompanied by significantly expanded workshop facility like new autoclave ovens and additional training for some technicians. On the other hand this is possible because of improvements in the area of bolted repairs and the provision of prefabricated repair kits. A few years ago this was still very uncertain and therefore the scepticism of experts was high. Of course it will take some more time to gain the same level of knowledge and to reach a similar routine in performing composite repairs as performing repairs to conventional materials like aluminum for example but we have to consider that this new material technology is a quantum leap similar to the change from wood to aluminum nearly 100 years ago. An important next step to improve the situation is to transfer the necessary knowledge in dealing with fiber composite materials from the well trained technicians in the specialized workshops to the maintenance technicians working on airports far away from the main maintenance bases. Unfortunately in this area there are still deficits visible. Thus, the downtime of a damaged aircraft can be reduced to an acceptable value and will increase the operational reliability and thereby ensures the economy of the new generation aircraft.

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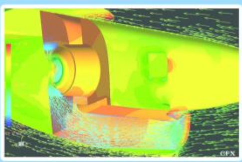


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